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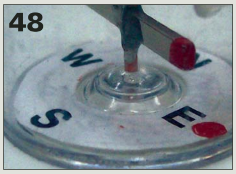
DECEMBER 2006

PROJECTS and FEATURES



ON THE COVER ...

Bob the Balancing Bot
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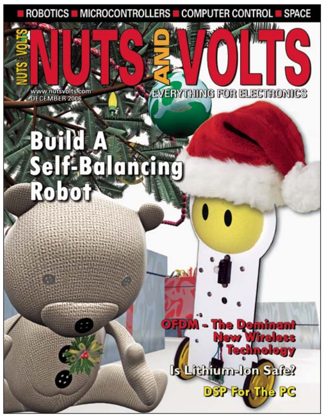

COLUMNS

DEPARTMENTS

Nuts & Volts (ISSN 1528-9885/CDN Pub Agree#40702530) is published monthly for $24.95 per year by T & L Publications, Inc., 430 Princeland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: Send address changes to **Nuts & Volts, P.O. Box 15277, North Hollywood, CA 91615** or Station A, P.O. Box 54, Windsor ON N9A 6J5; cpcreturns@nutsvolts.com

READER FEEDBACK

HOW LOW SHOULD THEY GO?

I am very appreciative of Ray Marston's many articles, I've learned a lot from them. However, in Part 3 of "Understanding Digital Logic ICs" (*Nuts & Volts*, September 2006), the transformer VA ratings given for the power supplies in Figures 1, 2, and 3 appear to be too low, with the transformers overloaded at the listed maximum outputs. Mr. Marston says that the volt-amp (VA) rating of the transformer should "at least double that of the final power supply's DC output." (I think that if volt-amps is used, it should be calculated at the input of the voltage regulator, not the output.)

Methods of calculating transformer power ratings do not seem to be widely known. I looked at about 10 electronics text books and reference books. Only one, *Reference Data for Radio Engineers* (Sixth Edition, 1977, Howard W. Sams & Co.), had information on calculating power ratings for power transformers. However, at least five manufacturers of transformers, and a few other sources, have published calculation methods.

All of them give a number which is multiplied by the DC output current to give the RMS current rating for the transformer secondary. (The RMS current rating of the transformer is usually higher than the DC output current because the current waveform in the transformer is not a sine wave, and the RMS of that waveform is higher than the DC output current.) This number is different for different rectifier and filter circuits. Four of the transformer manufacturers (Stancor, ATC-Frost, Signal, and MCI Transformer), as well as most other sources, have the number 1.8 for a full-wave bridge rectifier with capacitor-input filter. (That is, for one amp DC output current, the transformer secondary RMS current rating should be at least 1.8 amps.) The number is 1.64 in *Reference Data for Radio Engineers*, and the number from Hammond transformers is 1.6.

I use 1.8, as it is the most common number. Thus, for five amps DC (Figure 3), the transformer should be rated for at least nine amps RMS, which is 108 VA for a 12-volt transformer, and 81 VA for a nine-volt transformer. (The number in Figure 3 is 60 VA.) For 750 mA DC (Figure 2), the transformer should be 1.35 A RMS, which is 16 VA for a 12-volt transformer and 12 VA for a nine-volt transformer. (The number in Figure 2 is 10 VA.) Similarly, for 100 mA DC (Figure 1), the transformer should be 180 mA RMS, 2.2 VA for a 12-volt transformer and 1.6 VA for a nine-volt transformer. (The number in Figure 1 is 1 VA.)

Published data also includes numbers for full-wave center-tap and half-wave rectifiers, and for choke-input filters. The number usually given for full-wave center-tap rectifiers with capacitor-input filters is 1.2. (Hammond is 1.0 and *Reference Data for Radio Engineers* is 1.15.) The number *from Radiotron Designers Handbook* (Third Edition, 1940, RCA) is 1.12. TJ Byers had a discussion of transformer current ratings in Q & A, *Nuts & Volts*, January 2006, with some additional material in April 2006. The numbers he gave were similar to those from Hammond.

Also, for the five-amp supply (Figure 3), the AC RMS ripple current through capacitor C1 will be about 6.5 amps; for a few 22,000 µF capacitors the maximum ripple current rating is as low as 4.5 amps. This rating varies widely for different capacitors. The ratings are listed in the capacitor data sheets on the manufacturer's website, and a few are listed in the catalogs of Mouser and Digi-Key.

Bill Stiles
Hillsboro, MO

Continued on Page 96

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Published Monthly By
T & L Publications, Inc.
430 Princeland Ct.
Corona, CA 92879-1300
(951) 371-8497
FAX **(951) 371-3052**
Product Order Line **1-800-783-4624**
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Subscriptions
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P.O. Box 15277
North Hollywood, CA 91615

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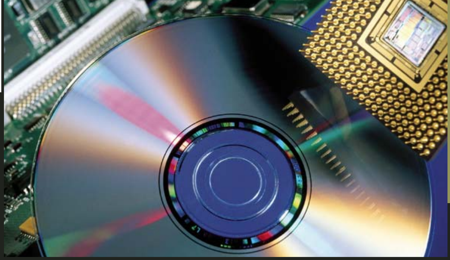

TECH KNOWLEDGEY 2006

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

"PHOTO FUSION" TO IMPROVE SOLAR CELLS

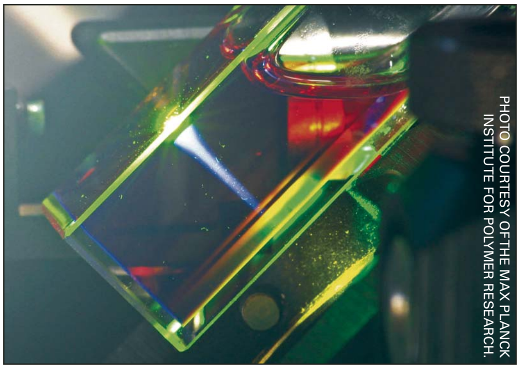

PHOTO COURTESY OF THE MAX PLANCK INSTITUTE FOR POLYMER RESEARCH.

■ In this wavelength-change experiment, the green light directed into the solution reappears as blue after it has been converted.

It isn't likely to solve our petroleum dependence problems overnight, but researchers at the Max Planck Institute (**www.mpg.de**), with assistance from the Sony Materials Science Lab (**www.stuttgart.sony.de**) have developed a new way of converting low-energy longwave photons into higher-energy shortwave ones, the latter of which can be converted into electricity by solar cells. While the effectiveness of the concept was not specifically quantified, it was noted that the result should be a "drastic increase" in cell efficiency.

Such photon fusion has previously been achieved with lasers, but this is a new approach. Here, the scientists used two substances in solution (platinum octaethyl porphyrin and diphenylan-thracene), which converted longwave green light from a normal light source into shortwave blue light. In a fairly complex chemical reaction, the platinum compound acts as an "antenna" for green light, and the other connects two low-energy photons to create a high-energy one, which it transmits as an "emitter."

Both molecules store the energy in excited states, after which one emitter molecule passes its energy to the other one and then drops back to its low-energy state. The double-charged emitter spits out a blue photon and then collapses to its original state. The emitted photon has a shorter wavelength and higher energy, but we aren't breaking any laws of physics here, because the total energy does not change. Continuing research will be directed at process optimization, including tests of other pairs of substances to convert other colors in the spectrum.

ELECTRIC CAR IS DIFFERENT KIND OF ANIMAL

PHOTO COURTESY OF TESLA MOTORS, INC.

■ The Tesla Roadster — to be available early in 2007 — is not exactly what you expect in an electric car.

Sometimes it seems like advanced technologies tend to consist of dry, academic research projects that will emerge in the practical world, if at all, only after years of refinement. But such may not be the case with the Tesla Roadster, an all-electric car that — aptly named in tribute to the Serbian-American researcher who discovered rotating magnetic fields — is set to debut in a matter of months. (Sorry, you can't get one in time for Christmas, but you can reserve one at **www.teslamotors.com**.) As you have already surmised from the photo, this is not your usual glorified golf cart, and the specs are rather amazing.

Would you believe 0 to 60 mph in four seconds, a top speed of better than 130 mph, and a powerplant that provides 100% torque from 0 to 13,000+ rpm? How about efficiency that is equivalent to 135 mpg and a range of 250 miles between charges? And you can recharge the batteries from your home power grid or even from a solar system (available at extra charge). Because of its wide rpm range, the car has only two forward gears, and, interestingly, it doesn't even have a reverse gear — you just run the motor the other direction. This conjures up the spectre of accidentally going from 0 to 60 mph in reverse, but maybe they have worked something out to prevent that.

So, you're asking, what's the catch? Well, assuming that the thing actually performs as promised, there seem to be only two problems. First, initially at least, you'll be able to get factory authorized service only in San Francisco, Los Angeles, Chicago, New York, and Miami. If you live more than 100 miles away from those areas, it will cost $8,000 to have a factory rep drop in. And, second, there is the price tag of $100,000. But, hey, it does include floor mats.

COMPUTERS AND NETWORKING

BIOMETRIC AUTHENTICATION HITS THE INTERNET

In the continuing fight to thwart identity theft, credit card fraud, and

PHOTO COURTESY OF PAY BYTOUCH™.

■ TrueMe™ — employing an integrated or USB-connected finger sensor — is said to be the first secure, on-demand biometric authentication system service on the Internet.

other Internet scams, Pay By Touch (**www.paybytouch.com**) has introduced TrueMe, a system that provides PC users with an easy and secure way to identify themselves and make transactions on the Web using their fingerprints. Available soon through a growing number of providers, all you will have to do is log onto a TrueMe-enables system and touch your finger to the sensor. Your fingerprint will be encrypted and combined with a unique device ID and then sent to a secure TrueMe authentication server. The server will then decrypt the data and validate that you are yourself and that you are authorized to use the device.

Finally, your authenticated identity is securely transmitted to the website or service that you want to use, such as online banking, e-commerce, and ISPs. According to the company, more than three million notebooks have already been shipped with integrated finger sensors, so watch for the service to become available at your favorite sites.

THIS SITE REALLY BITES

You likely remember him from the 1980's Neighborhood Watch campaign, radio and TV appearances, and perhaps even the 1984 first-class postage stamp bearing his image. You may have seen him battling schoolyard bullies and people who take advantage of senior citizens. He has appeared at schools and county fairs in your locale, and he even once rang the closing bell at NASDAQ. Yes, it's McGruff the Crime Dog®, and he's back. After being on the job in the physical world since about 1980 (which makes him 182 in dog years), he is now being redeployed to protect both children and adults against cyber crime.

Putting aside tempting jokes about carpal paw syndrome and cyber hydrants, it is probably worthwhile to mention the "Take a Bite Out of Cyber Crime" campaign (**www.bytecrime.org**), which is a joint project of the National Crime Prevention Council, the Chief Marketing Officer (CMO) Council, and the Forum to Advance the Mobile Experience. It is being underwritten by a range of high-tech and media companies, including Comcast, Intel, McAfee, et al., and other companies are encouraged to join in.

The campaign is intended to reach millions of computer users nationwide and to provide tools and education to avoid being victimized by crooks, hackers, child predators, and other unsavory characters, so even if you have doubts about the efficacy of canine cartoon cops, you may as well log on and take a look at the suggestions. If nothing else, you can get $20 off the list price of the McAfee Internet Security Suite or, if you prefer, a 30-day free trial version.

PHOTO COURTESY OF CMO COUNCIL.

■ The "beloved" crime dog — McGruff — is now sniffing out cyber crime.

CIRCUITS AND DEVICES

NONMAGNETIC INDUCTORS INTRODUCED

The new MG inductor series from Gowanda Electronics (**www.gowanda.com**) is designed specifically for applications that are magnetically sensitive and therefore require nonmagnetic components. Examples include test equipment and devices, and medical diagnostic equipment — particularly imaging devices such as MRIs and some types of X-ray equipment. The inductors (in their role as filters) block certain frequencies that otherwise would compromise the performance of the equipment or device. It is also anticipated that they will find applications in telecommunications, security systems, instrumentation, laboratory analysis equipment, aviation equipment, and navigation systems.

PHOTO COURTESY OF GOWANDA ELECTRONICS.

■ The MG series inductors are safe for magnetically sensitive environments.

The series is available in both through-hole leaded and SMT versions. Technical specs include inductance from 0.01 to 4.7 H and current ratings from 260 to 3835 mA DC. Numerous self-resonant frequencies are available, ranging from 90 to 1,800+ MHz. A RoHS compliant version is also available. Pricing starts at $0.79 each in production quantities.

LAST-CHANCE STEREO DISCOUNT

■ A pre-Christmas promotion saves on an Alpine sound system.

PHOTO COURTESY OF ALPINE ELECTRONICS, INC.

If someone in your family doesn't particularly care about the folks in nearby cars, or the condition of his eardrums, Alpine Electronics (**www.alpine-usa.com**) has a promotional package that could solve your gift-giving dilemma. Until December 25

INDUSTRY AND THE PROFESSION

VOODOO AT HP

Hewlett Packard (**www.hp.com**) has put its feet squarely in the gaming computer market with the acquisition of VoodooPC (**www.voodoopc.com**), a Calgary-based manufacturer of high-performance systems such as the OMEN — a water-cooled Intel Core 2 Duo based machine that starts at about $6,000. According to reports, the company's co-owners will stay on in management positions, reporting to HP's Phil McKinney. The acquisition is expected to extend HP's presence into the high-performance gaming market, as well as globally expand the reach of the VoodooPC brand.

"SPAM" ON TRIAL

For those who are enthusiasts of Spam® (which is to say the pork product, not the unwanted email), the news may be a little disappointing. Hormel Food Corp. has lost a legal battle to prevent software companies from using it in their names — at least within the European Union. Hormel has been involved in disputes about the word in the USA and elsewhere, objecting to such products as Spam Arrest, BopSpam, and others. The company apparently believes that its trademarked name, in use since 1937, is being diluted by unauthorized use. Could be, but it might also be viewed as free publicity. After all, how often has someone emailed you "treet?"

only, participating Alpine retailers are offering a 400W sound system that includes a CDA-9856 CD/MP2/WMA Ai-NET receiver, a KCE-422i iPod® connection cable, an MRP-M450 mono amplifier, two pairs of SPS-17C2 6.5-in speakers, and an SWS-1042D 10-in dual subwoofer.

Buying the components separately would involve shelling out $880, but the package is $699 (plus installation), which is only slightly more than my car is worth.

ONE MORE SUGGESTION ...

As a final hint for the holidays, you might consider a gift that is both a gadget and a hobby. The practice of "geocaching" is growing by leaps and bounds, driven by the increasingly low cost of GPS units. Geocaching — if you aren't familiar with it — is a widely practiced activity, sort of like a scavenger hunt, in which people place a logbook or inexpensive "treasure" in a waterproof container, hide it, and then post the GPS coordinates on a related website (e.g., **www.geocaching.com** and **www.terracaching.com**). The geocachers then track it down and sign the logbook or take the treasure, being sure to leave something equally nonvaluable in its place. A cache in my neighborhood, for example, originally contained two bird figurines, a wind chime, a flamingo pin, a shark's tooth key chain, and assorted other items. I think I finally know what I'm going to do with the bobble-head hula doll that I received last year.

In any event, all you need to participate is a cheap GPS, an example of which is the Magellan eXplorist 100. Even though it can be had on the street for less than $100, the unit can fix on up to 14 satellite channels, log 500 points of interest and 20 return routes, an is accurate to within 3 m. For details, see **www.magellangps.com**. **NV**

PHOTO COURTESY OF MAGELLAN NAVIGATION, INC.

■ Magellan's eXplorist 100 GPS — an entry-level unit suitable for geocaching.

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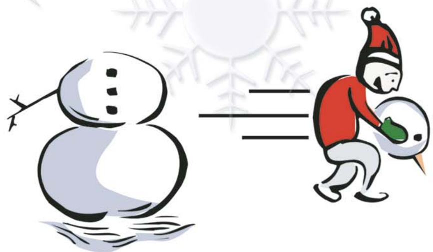

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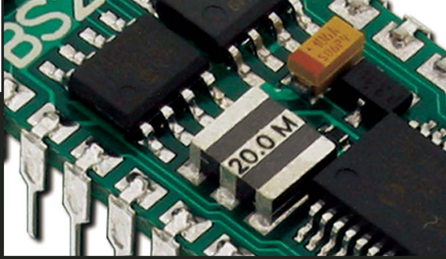


STAMP APPLICATIONS

PUTTING THE SPOTLIGHT ON BASIC STAMP PROJECTS, HINTS & TIPS

■ BY JON WILLIAMS

CELEBRATING THE SEASON

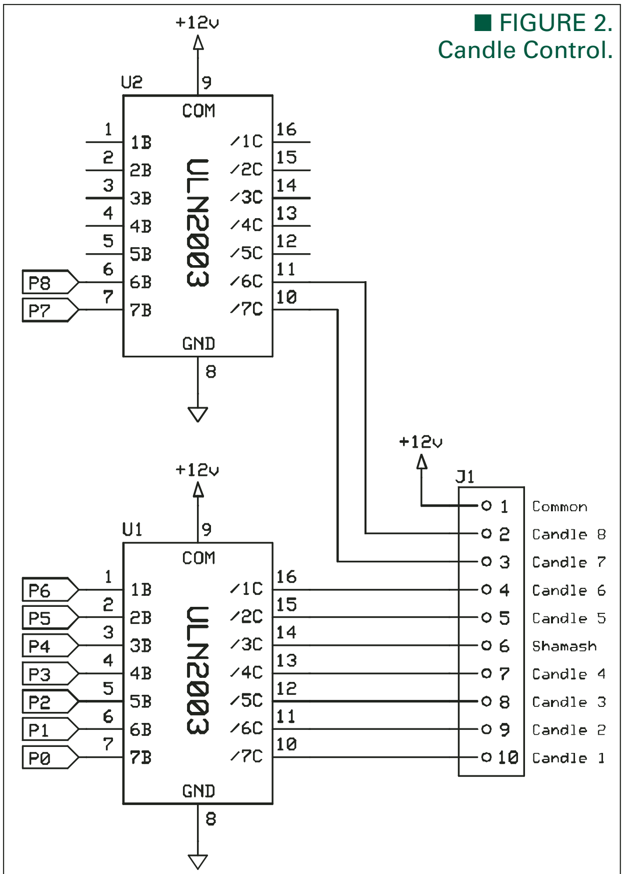
AT THE RISK OF REPEATING A COMMENT I think I make every December ... I love this season! Sure, I could live without the cold weather, but the smell of fireplaces burning and holiday decorations everywhere I look just makes it all okay — even if I do have to put on long sleeves and a jacket before I go out. While many of us think about Christmas this time of the year, our Jewish friends enjoy a special event, as well — Hanukkah (the Festival of Lights). A key element in the Hanukkah ritual is the Menorah — a special candelabra used to commemorate the eight days of the celebration. This month, we're going to build a Menorah — an electronic version, that is.

Some of you will remember the faux candles project we did in October '05. Well, the faux candles generated more email and phone calls than anything I've ever written about in this column — ever! The response has been amazing, and continues to this day. In the scheme of the prop-related programming I've done over the last year and a half, I think more than half of those projects (requested by others) have involved faux candles. One of the requests was for a "magic candles" prop that would light candles in a specific sequence, and that lead me to what we're doing this month.

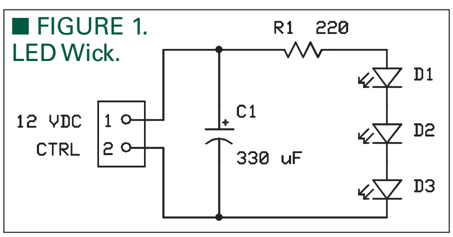
The reason for the electronic Menorah is a bit personal. No, I'm not Jewish, but one of my dearest friends, Jenny, is — or, more accurately, is becoming. Religion is a deeply individual matter and I have great respect for any person who practices their religion faithfully while letting others do the same, and I stand in absolute awe of those who make the conscious decision to change. Religious conversion is a very serious undertaking, and my gift to Jenny this December is a decorative electronic Menorah to commemorate the commitment to her new religion.

Let's get right to it. I've made this very simple because Jenny, while a wonderful actress, really doesn't like to fuss with high-tech gadgets. What this means is that she'll simply have to plug it in at the beginning of each evening of Hanukah and unplug it before she goes to bed. The program will advance the day automatically, so there are no controls or settings to worry about (she'll like that!). Another choice I made, after consulting a Jewish friend, is that my Menorah has all candles installed all the time. In the actual Hanukkah ritual, one candle is added each day and then lit in a specific sequence. This design is not really intended to be used in religious services, but rather as a commemorative decoration. If you decide to

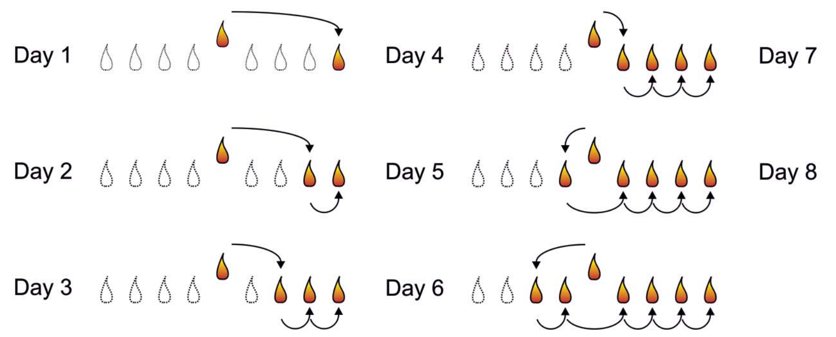
■ FIGURE 2. Candle Control.



■ FIGURE 1. LED Wick.



make a version to be used in services, you might consider adding plugs to the candles with matching sockets on the Menorah.



■ FIGURE 3. Menorah Lighting Sequence.

FLICKER AWAY

Simulating candle flicker — using just an LED — is not terribly easy with the BASIC Stamp due to the instruction fetch (from external EEPROM) and decoding; this makes using the **PWM** instruction a bit fruitless. My friend John came up with the candle circuit (see Figure 1) that cheats a bit by using a capacitor. When the control line is connected to ground through a device like the ULN2003, the LEDs will light and the capacitor will charge. When the control line is released, the capacitor will discharge through the LEDs providing a slow fade, eliminating the digital nature of the controller output, giving more of a candle-like effect. Note that the control line needs an open-collector type control; do not turn the "wick" off by making the control line high as this will defeat the operation of the capacitor in the circuit. We'll use two ULN2003 Darlington arrays to control the candles. The schematic for the candle driver is shown in Figure 2.

One of the aspects I enjoy most about prop programming is the simulation of real events. In the Hanukkah ceremony, the "servant" (*shamash* in Hebrew) candle is lit first and then used to light the other candles in a specific sequence. Candles are inserted into the Menorah from right-to-left, but actually lit from left-to-right. As I stated earlier, my Menorah has all of the candles pre-installed so the only thing to consider is the lighting sequence. Figure 3 shows the lighting sequence for the eight days of Hanukkah.

There are any number of ways we could approach the coding of this project, but I tend to lean toward the idea that simple is best. To that end, I decided to put the lighting sequence into a set of DATA tables and pull them out as needed for the current day in the cycle.

Let's have a look at the sequence for day eight:

```
Wicks8          DATA    Word %000010000
                DATA    Word %100010000
                DATA    Word %110010000
                DATA    Word %111010000
                DATA    Word %111110000
                DATA    Word %111111000
                DATA    Word %111111100
                DATA    Word %111111110
                DATA    Word %111111111
```

As you can see, there is one table entry for each candle lit. We start with the shamash (BIT4) and then work left-to-right from candle 8 to candle 1. We'll control the timing between each line to simulate a person moving a match from one candle to another.

At the top of the program, we'll set our candle pins to outputs and then read the current day of the cycle from an EEPROM location.

```
Reset:
  DIRS = $01FF
  READ Day, dyNum
```

Once we drop into the main body of the program, the day number is used to fetch the address of our candles table using **LOOKUP**.

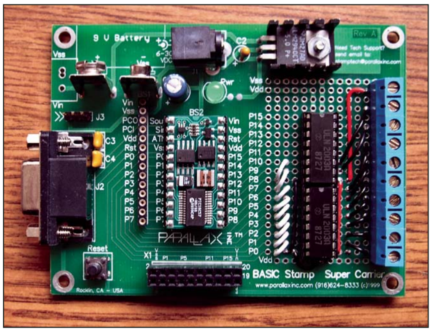
```
Main:
  LOOKUP dyNum-1, [Wicks1, Wicks2, Wicks3,
                  Wicks4, Wicks5, Wicks6,
                  Wicks7, Wicks8], addr

Light_Candles:
  FOR cycle = 0 TO (dyNum * 2) STEP 2
    READ addr + cycle, Word mask
    GOSUB Flicker
  NEXT
```

A simple loop iterates through the table entries, moving the values from the table into a variable called *mask*. Note that we're multiplying the day number by two and using a **FOR-NEXT** step value of two as the mask values in the tables are Words (two bytes each). Once the mask has been read for the sequence element, this is passed on to the Flicker subroutine where it is used to selectively enable specific candles.

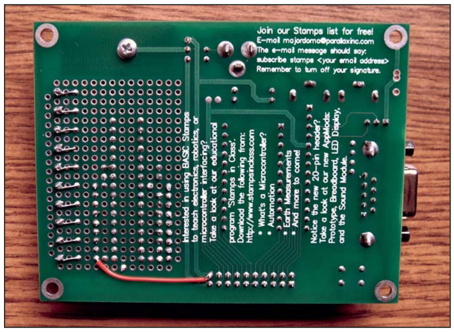
```
Flicker:
  timer = 0
  DO
    FOR idx = 1 TO 3
      RANDOM wicks
    NEXT
    Candles = wicks & mask
    delay = wicks // 26 + 25
    PAUSE delay
    timer = timer + delay
  LOOP UNTIL (timer >= 1000)
  RETURN
```

The purpose of this subroutine is to light the selected candles for one second, simulating the time to move from one candle to the next as if lighting real candles with a match. At the top of the subroutine, the **RANDOM** function is called in a small loop.

Why do this — the result is random, right? Well, sort of. Remember that the **RANDOM** function uses a *Linear Feedback Shift Register* and if we don't call **RANDOM** at least three times we can actually see the movement of the bits through the LFSR in the parallel output of the candles.



■ FIGURE 4. Menorah ontrol — top.



■ FIGURE 5. Menorah control — bottom.

For pure numeric use, this isn't necessary, but if we're dealing with parallel outputs like the candles in this project, it's best to call **RANDOM** at least three times. I've experimented with other values, and three seems to work best.

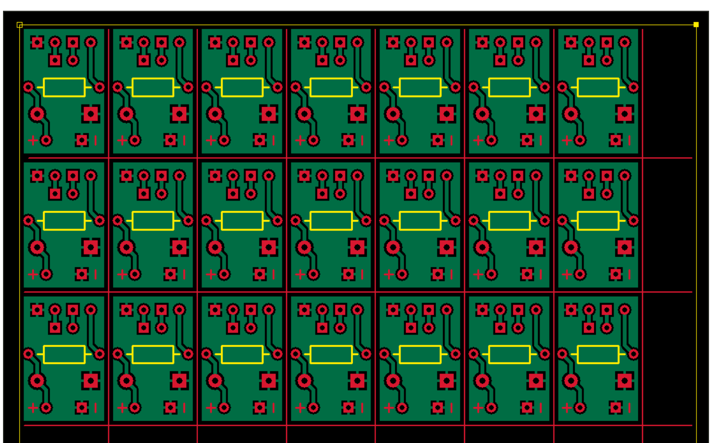
Now that we've got an apparently random set of bits we can do a bitwise AND with the mask to disable those candles that are not supposed to be lit at this moment. A small, somewhat randomized delay is derived from the random number and this value is added to an accumulator. Once we have "lit" candles for about a second, we can return to the caller.

From time to time, I get questions on creating a random value between X and Y. First, we need to call **RANDOM**, and doing it frequently is best. The general formula, then, works out like this: *value* = *random_number* // (X + Y + 1) + X.

This works because the modulus operator returns a value between zero and the divisor minus one — this is why we add one to the span for the formula.

Back in the main section, we can increment the day pointer and write it back to the EEPROM for the next cycle. As you can see, we use our friend the modulus operator to wrap the day value from eight back to one, making the Menorah ready for next year.

```
Update_Day:
  dyNum = dyNum // 8 + 1
  WRITE Day, dyNum

  DO
    GOSUB Flicker
  LOOP
```



■ FIGURE 6. Wick PCB Panel.

The end of the program we enter an infinite loop that flickers the day's candles — and that's all there is to it. This is a very simple program, and when combined with the beauty of the electronic wicks, it results in a beautiful display.

PUTTING IT TOGETHER

Since the Menorah control section is a one-off project, I decided to make things easy by assembling the ULN2003 output drivers and terminal blocks on the Parallax BASIC Stamp Super Carrier. This board will hold any 24-pin BASIC Stamp module, the Javelin Stamp, and even the BS1-IC if you like (which won't work for this project because we need nine outputs). The board has a 2.1 mm barrel connector for power, a beefy five-volt regulator, and a standard serial connection for programming the BS2 or Javelin. For $20 (which does not include a BASIC Stamp), this seems like a really good deal, especially when one considers the time and energy to lay out a custom PCB, or hand wire the whole works.

The user section of the Super Carrier has convenient dog-bone pads that make adding the two ULN2003s a breeze. I got a bit lucky in that I could just fit five, two-position terminal blocks (found them at RadioShack) into the board for the common plus nine wick control outputs. Everything is connected with point-to-point wiring using #26 gauge solid wire. I kept all connections on top, save one, as the easiest place to grab the Vin voltage was from the AppMod header. I removed the solder from this pin and made the V+ connection there. Figures 4 and 5 show the top and bottom of the completed control board.

I just said that I wouldn't lay out a board for the control section, but for the wicks I sing a completely different tune. I have hand-wired wicks in the past and believe me, it is not any fun at all. If you're going to do just one small project, that would be fine, but if you are going to build more than one project with the faux candles, you can either get them pre-built or build your own wick PCB.

I've saved you the trouble of laying out the wick PCB. In the download file, you'll find a panelized PCB in ExpressPCB (**www.expresspcb.com**) format. ExpressPCB offers great service and very good prices, and I use them frequently when prototyping devices for my clients. The wick PCB is small, and as you can see in Figure 6, 21 wick boards will fit onto a "mini board" PCB. What this means is that for a standard order of three mini boards, you'll end up with 63 wicks — that's a lot of candles, and a possible opportunity to split the board cost among friends!

The wicks are installed in short, pillar-style candles because these are the easiest to work with. After burning them for an hour or so to create a bit of a well, a 1/2" hole is drilled through the centerline to make room for the electronic wick. Use a wood boring bit and do go slowly; I learned the hard way that getting too aggressive can cause the candle to split. After coring the candles, I did a little additional sculpting with a knife and then smoothed everything with a butane torch. The wicks are installed from the bottom side of the candle so that the tops of the LEDs nearly protrude from the core.

Please, please, please ... be safe when burning your candles and do make sure you do this in an area clear of flammable debris. Do not leave them to burn while unattended.

Finally, I asked around and found there is no specific requirement for the construction of the actual Menorah other than the central (shamash) candle being higher than the others, so I turned to master woodworker, Jeremy Black, for help. I wanted simple elegance, and Jeremy gave it to me in spades. My Menorah is a gorgeous oak platform that is large enough to accommodate nine, three-inch pillar-style candles. Since the platform is flat, I used a six-inch tall candle for the shamash.

The only thing I didn't specify for Jeremy — which nearly got me — was the size of the PCB I intended to mount underneath the platform. As luck would have it, the Super Carrier just fit when I mounted it vertically. I think that you'll agree the final piece is beautiful, and I expect Jen will get many years of enjoyment from it.

Hopefully, this project will give you ideas for additional holiday projects. For those that are fans of the Rogue uMP3 player (we used this last December), a fun project might be a "dancing candles" display that lights candles in sync with your favorite holiday song. After starting the audio, you can read the "candle dance" out of a **DATA** table as we did in this project. Hmmm, where's my uMP3 player? ...

RESOURCES

JON WILLIAMS
jwilliams@efx-tek.com

PARALLAX, INC.
www.parallax.com

ROGUE ROBOTICS
www.roguerobotics.com

HAPPY HOLIDAYS

■ FIGURE 7. Completed Menorah.

Well, that about wraps it up for another month and indeed another year. From my family to yours, let me wish you a very happy holiday season filled with peace and love, and a terrific new year for you and those in your life.

So everyone, until 2007 ... Happy Stamping! **NV**

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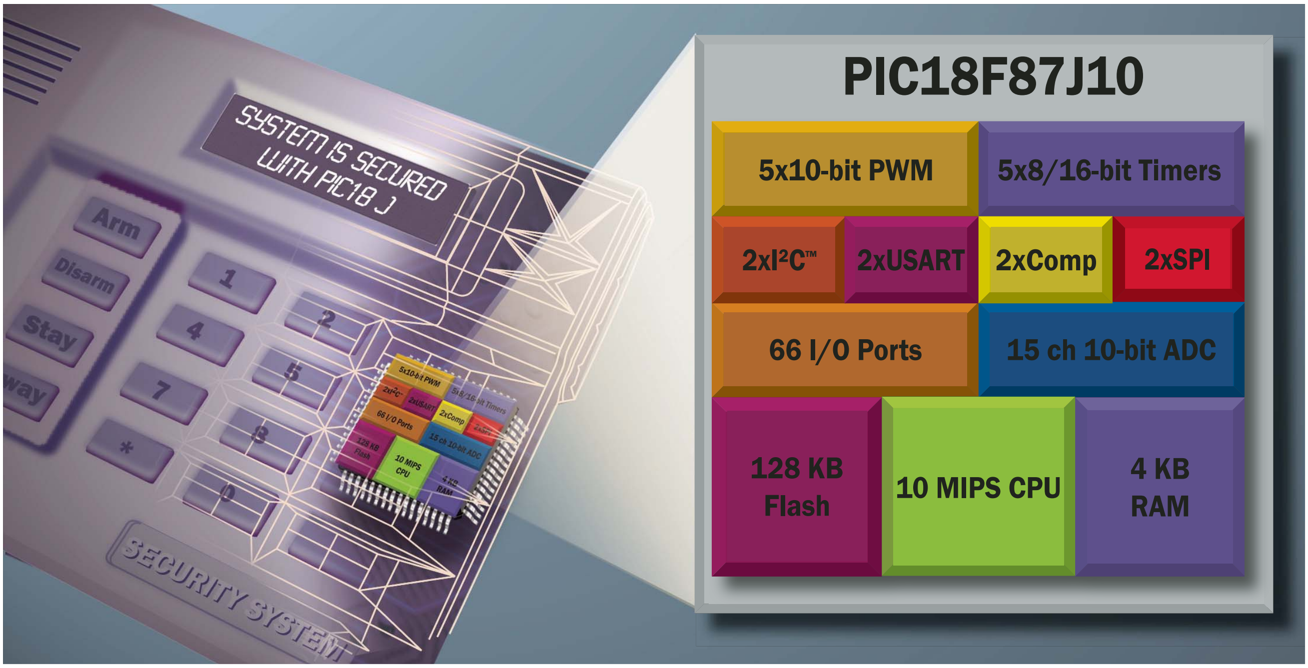

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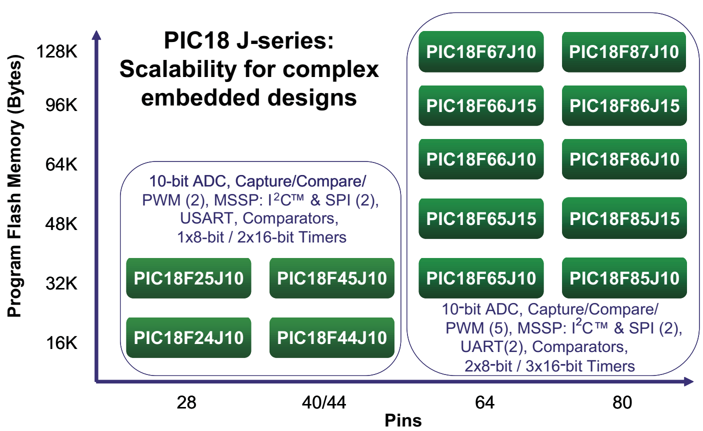

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Q&A

WHAT'S UP:

Understanding and using hysteresis. More bounceless switches. Six winter projects.

- ✔ **Overcurrent indicator.**
- ✔ **High-intensity lamp dimmer.**
- ✔ **Home energy sniffer.**
- ✔ **Sonic snow pole.**

■ WITH TJ BYERS

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, comments, or suggestions.

You can reach me at: **TJBYERS@aol.com**

SOUND OR SCHMITT?

Q I am a university student studying electronics and I have yet to see a satisfactory explanation of Schmitt triggers. Particularly, what is the difference between positive and negative feedback? Why does positive feedback cause oscillation in one configuration and eliminate it in another? And why does the Schmitt trigger circuit follow the hysteresis curve the way it does?

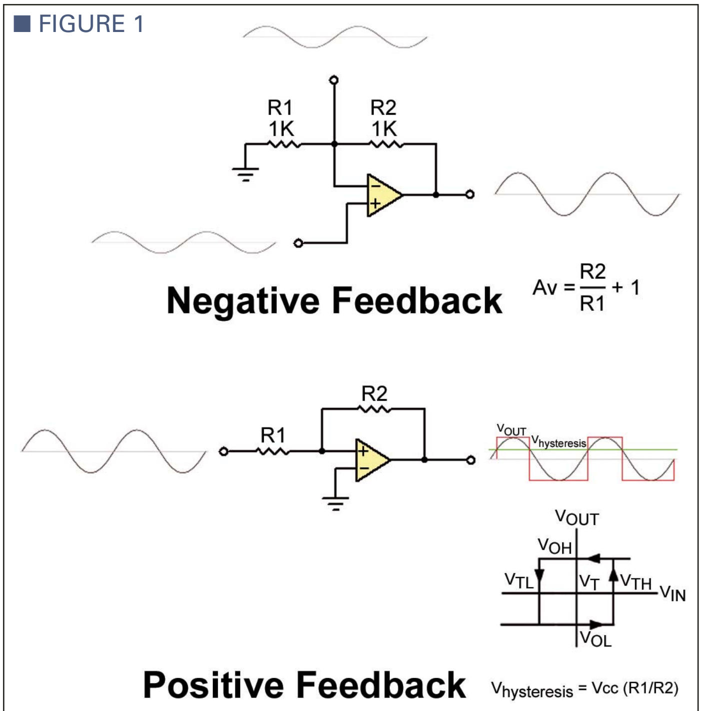
— Peter

A Let's start by defining feedback. Feedback is any force or influence — electrical or mechanical — that invokes a change on another electrical or mechanical element. A perfect example of feedback is your room air conditioner. When the room gets too hot, the air conditioner turns on. Once the room is cooled to satisfaction, the air conditioner turns off. The process of turning the unit on and off is the result of feedback from a thermostat.

Feedback is controlled in loops; loops that feed back information from the output to the input. Feedback can be digital (as in the example of the air conditioner) or linear in nature. When used in electronics, the feedback is typically linear. When the feedback is negative, the output subtracts something from the input, as shown in Figure 1. An ideal op-amp is assumed to have infinite gain. That is, without feedback, a microvolt at the input can theoretically transform to one million volts at the output. (In reality, most op-amp gains are limited to 10,000.) To control the gain of the op-amp, a negative voltage is mixed with the positive input voltage by injecting a part of the output into the inverting input. This mixing of positive and negative reduces the gain of the op-amp and gives us a handle on a precise value for the amount of amplification. The gain is controlled by the ratio between R1 and R2. If both resistors are equal, the voltage gain is 2: Av = (R2/R1) + 1.

Positive feedback has just the opposite effect. It adds positive output voltage to the positive input voltage. The output voltage is now reinforced rather than diminished. A small amount of positive feedback will cause the op-amp to oscillate — as in when a PA microphone feeds back to the speakers to cause that excruciating squeal. A large amount of feedback causes the output to latch in one of two states: either full on or full off. The output state can be changed only if the input overcomes the positive feedback to trip the balance of powers. This is a dead zone known as *hysteresis*. Inside this zone, no change in the output

■ FIGURE 1



voltage can occur. The wider the hysteresis, the more voltage swing it takes on the input to toggle the output. Hysteresis is equal to the ratio between R1 and R2: $V_{hysteresis}$ = Vcc (R1/R2). If R1 equals 10K and R2 equals 100K, then the hysteresis band gap is 0.5 volts (with a Vcc of five volts). This means that the input voltage must swing a full 0.25 volts either side of the switching point before the output will follow suit.

ENOUGH, ALREADY

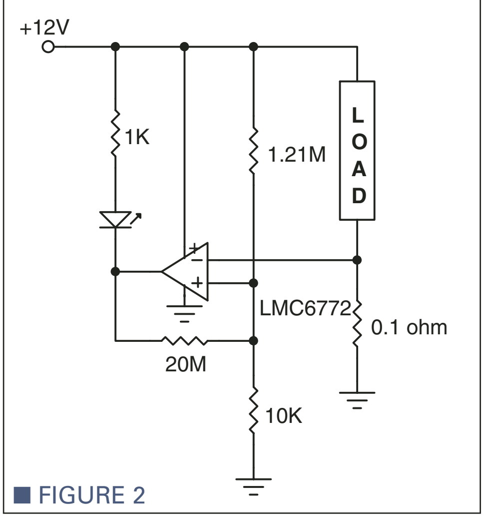
Q After building a simple 12-volt power supply with a 7812, I wondered how I would know if I am close to, or exceeding, the one amp rating of the 7812 without hooking up a VOM or ammeter. I want to construct a small circuit that would detect the output current of the 7812 and have an LED light up (or slowly ramp up) when the load reaches one amp.

— Niles Russell
Chandler, AZ

A What you want is a voltage comparator that monitors the voltage across a small current sensing resistor and lights an LED when the output current exceeds one amp, as shown in Figure 2. The non-inverting reference is held at 98 millivolts (mV) by the 1.21M/10K resistor divider. At one amp, 100 mV develops across the 0.1-ohm sensing resistor which, in turn, is fed to the inverting input of the comparator. To prevent "hunting" by the LED at the one-amp crossover point, a small amount of hysteresis (6 mV via the 20M resistor) is added to the comparator. Hence, the LED won't turn on until the load current exceeds 1.01 amps, or go off until the current drops below 0.95 amps. The over-current LED can operate over a voltage range of three to 15 volts, and the current alert can be adjusted to any load you wish by playing with the value of the 0.1-ohm resistor. For example, a 0.2-ohm sense resistor will flash an over-current alert at 500 mA. An open-drain transistor drives the LED.

While this circuit is simple and reliable, don't be tempted to substitute just any old comparator or op-amp for the LMC6772. That's because the current-sensing resistor is referenced to ground. Consequently, the comparator must have a rail-to-rail input. An LM324 isn't R-to-R and won't work. Although it's possible to move the sense resistor to the high side of the load — thus eliminating the need for R-to-R inputs — doing so can create stability problems.

1A Overcurrent Indicator



■ FIGURE 2

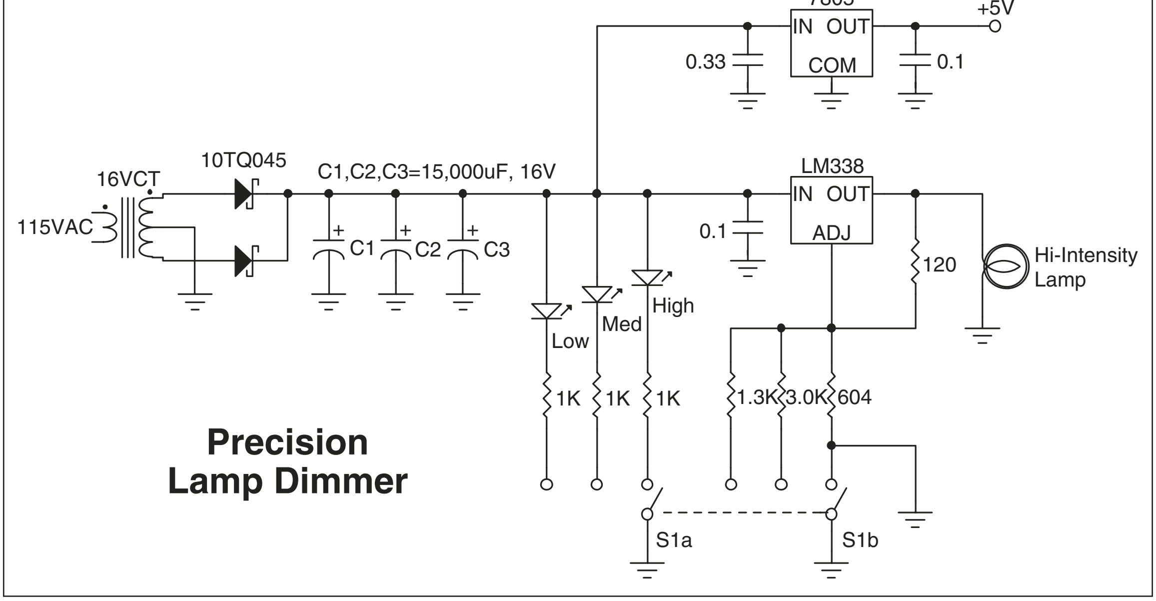
THE EYES HAVE IT

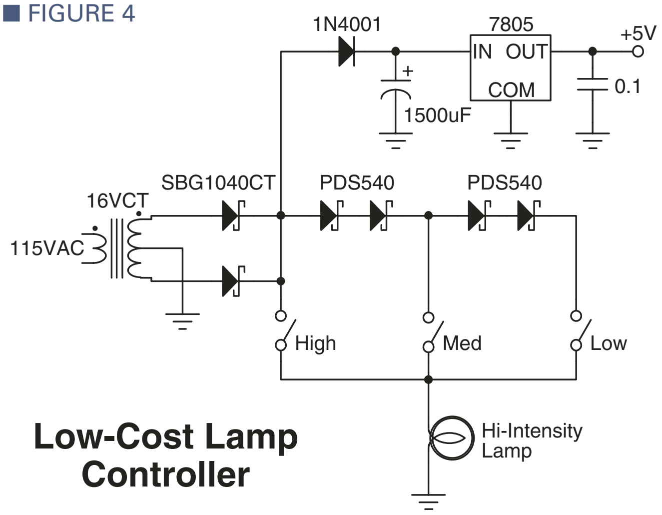
Q I have an old Ophthalmology slit lamp that uses a 110 VAC step-down transformer that delivers 5.5, 6.5, and 7.5 volts to the high-intensity lamp. The transformer is history, both in functionality and availability, and I want to build a DC power supply to fit in the same box. The new power supply needs to deliver selectable voltages of 5.5, 6.5, or 7.5 volts DC at five amps — plus a constant output of 5.0 volts at 0.18 amps. How can I design such a circuit?

— JMH

A By using an LM338 adjustable voltage regulator. This regulator can output five amps and is adjustable from 1.25 volts on up to 32 volts using just two resistors, and comes in a small three-lead TO-220 package. The output voltages for your high-intensity lamp are determined by three fixed resistors: 410 ohms for 5.5 volts, 505 ohms for 6.5 volts, and 604 ohms for 7.5 volts (Figure 3). Each resistor is

■ FIGURE 3



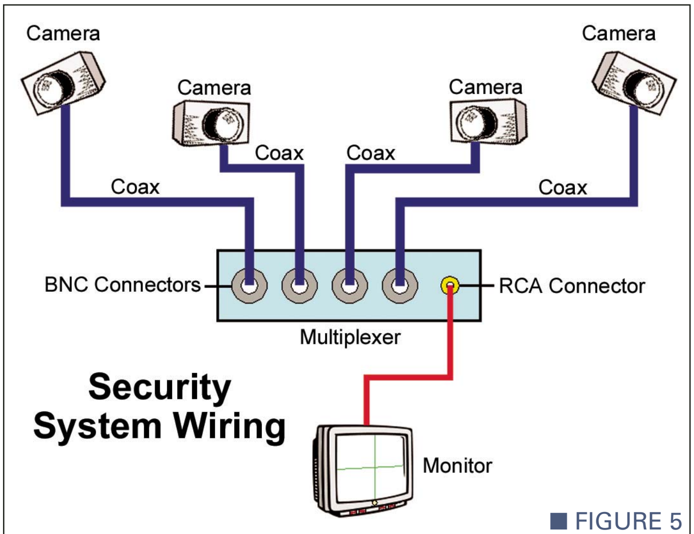


■ FIGURE 4 Low-Cost Lamp Controller

switched into place using a rotary switch. Ideally, the rotary switch has make-before-break contacts. Without this feature, it's possible to find a position on the switch where all resistors are left dangling — a situation that would cause the output voltage to rise above 10 volts and stress the lamp, if not destroy it. To prevent a runaway voltage scenario, I opted instead to tie the 604 ohms to ground and use parallel resistors to obtain the values of 410 and 505 ohms (well, close enough for government work, anyway). This way, the output voltage can never rise above 7.5 volts even with an open switch. A second section of the rotary switch lights an LED that indicates the output voltage to the lamp.

Because of the high currents and low voltages involved, I used Schottky diodes (with a typical 0.56-volt forward voltage drop) instead of industrial strength silicon rectifiers (with voltage drops in excess of 1.5 volts) for the power supply. The power transformer can be any center-tapped unit with a secondary voltage of 16 to 20 volts at five amps or better. Three filter caps are wired in parallel in place of one large cap to lower the equivalent series resistance (ESR). In operation, the LM338 can dissipate as much as 30 watts, so make sure you secure it to a suitable heatsink. The five-volt output is provided by a 7805 linear regulator, which needs to shed 1.5 watts at 200 mA; a small clip-on heatsink should suffice.

Now that I've given you the Cadillac of high-intensity lamp controllers, let me show you how I'd approach the problem using just diodes. The trick is to match the diode's forward voltage drop with the voltage drop needed by the tap. For this, I went to the datasheets of Diodes, Inc. (**www.diodes.com**), and matched forward currents to forward voltages to arrive at the design in Figure 4. The power dissipation is reduced from 30 watts to 12 watts and the part count is cut by one-half. I was also able to eliminate the filter caps (the original AC transformer didn't have filtering), thereby reducing construction cost considerably. Unfortunately, you can't substitute the transformer; it must be 16VCT for proper voltages. And make sure you use heavy-duty toggle switches with a rating of five amps or better.



Security System Wiring ■ FIGURE 5

I SPY

Q My building's security system displays the output of four cameras on one TV screen by dividing the screen into quadrants. However, I am only interested in the output of one camera. How can I enlarge the single quadrant so that it fills the screen? The source is composite video and will be displayed on a dedicated monitor.

— Walter

A The camera itself generates a full screen. What makes it into a quadrant is the video multiplexer between the four remote cameras and the single monitor, as shown in Figure 5. Inside the multiplexer is a computer that takes the images from each of the four cameras, stores their line-by-line information in memory, then paints the screen by selectively pulling video lines from the memory. Which means if you unplug video remote #1 from the multiplexer and plug it into your monitor, it will be full screen.

But I'm sure your building's management company will frown on that practice. What you can do is split the signal using a BNC tee so that the signal goes both to the security monitor and your maverick satellite monitor. Because most video composite monitors sport an RCA video socket, you'll need two adapters. The first is a BNC T-adapter. like the RadioShack 278-112. The second is a BNC-to-RCA adapter — RadioShack 278-303. Be aware that you are now sharing the video signal, which may degrade the quality of the image. If this happens, you will need to insert a line amplifier before the split — like the RadioShack 15-1170.

In rare cases, you may encounter a camera with an RJ11-E connector, as would be the case with a remote camera with no access to AC power. Two of the wires in the RJ11-E cable send power to the remote camera. If this is the case, you will need an adapter from places like SecurityandMore (**www.securityandmore.com/cctv2.asp?Model_ID=160&Task=Detail**).

BUZZING BULBS, ANYBODY?

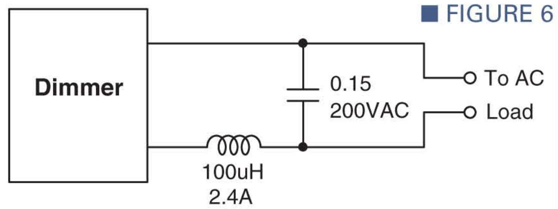
Q When using lamp dimmers (wall switch type), what is the best way to stop triac switching interference — particularly RF noise in radio receivers? I thought a cap was used years ago for a fix, but I've had no luck.

— Chuck Barnes

A Dimmers are supposed to have filters in them, but many cheap dimmers economized on the manufacturing costs by minimizing the filtering. The result is RF interference (RFI) and lamp buzz. The filter's job is to "round off" the sharp corners in the chopped wave form, thereby reducing EMI, and the abrupt current jumps that can cause RFI buzzing. This can be done using an LC combination of a series inductor and parallel capacitor (Figure 6). Place the components as close as possible to the dimmer itself to prevent RF radiation via the house wiring. If you can't find a 100 µH choke, you can make your own by winding 40 turns of 18 AWG wire (two layers) around a 1/4" by 1.06" ferrite toroidal core.

Another sign of a cheap dimmer is buzzing bulbs. That's because a bulb consists of a series of supports and fine coils of wire. When the current flow abruptly changes, the magnetism change can be much stronger than it is on a simple sine wave. Consequently, the filaments of the bulb will vibrate more with a chopped sine wave than with a true sine wave. Lamps with a power rating of 100W and above are more likely to emit acoustic noise when dimmed than smaller-wattage bulbs. The addition of a series choke with a one ms time delay helps to eliminate lamp singing (see Cool Websites for a cool LC calculator).

■ FIGURE 6



Dimmer RFI Filter

IEEE-488 TO USB

Q I have several older pieces of test equipment that were used with HP computers. Therefore, they have an HPIB bus. Is there some way to interface these instruments to the USB bus of my Compaq computer?

— John R. Seeley KI4LTB
Palm Bay, FL

A Hope you have deep pockets, because you'll need them. Although the HPIB has evolved and became the IEEE-488 standard, it is still a parallel interface. The USB port, on the other hand, is serial. Which means you need a data buffer — typically EEPROM memory with a controller — to convert the parallel data into a serial stream, and vice versa. This is where the big bucks come in. The converter you ask for runs about $500. What you need to do is weigh that cost to the price of replacing your equipment with USB or Ethernet interfaces, both of which are the future of PC-connected test equipment. Me? I'd spring for the IEEE-488 converter today and upgrade to USB as my testing demands increased. Check out the websites below:

http://sewelldirect.com/GPIB

www.home.agilent.com/USeng/nav/-12115.536881832/pd.html

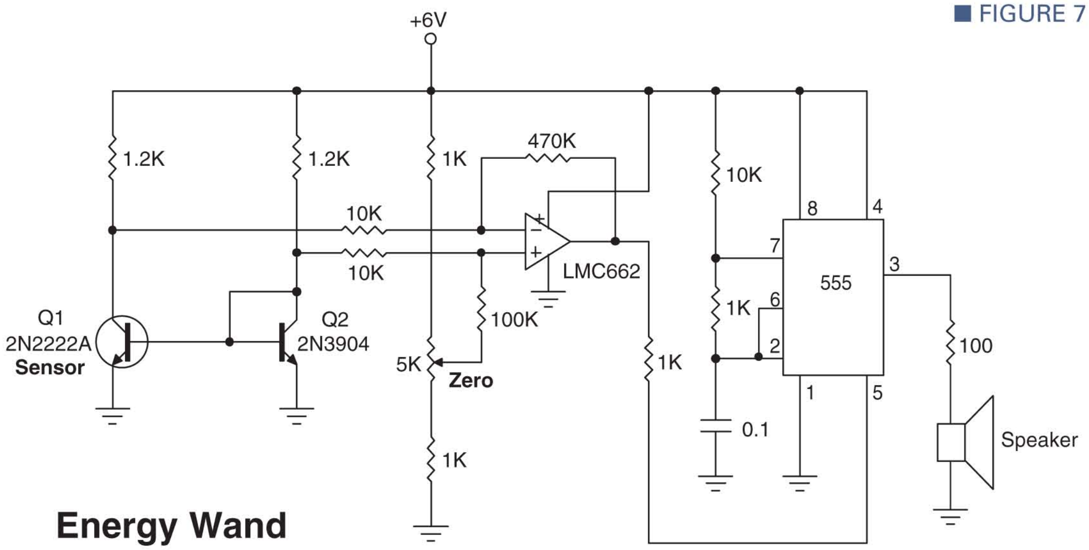
THE CHILL CHASER

Q With heating bills increasing, I thought an interesting project for you to explore would be some type of device to measure areas in the house where heat is escaping. Maybe some type of poor man's infrared camera or other heat sensor that could indicate where more insulation or weather-stripping was needed.

— Jeff Miller
Roswell, GA

A Actually, the wavelength range of a digital camera — even with infrared filters — doesn't extend down to the range of "leaky house." For those readers who buy their heating from a public utility, most of these companies will do a free energy analysis of your home

■ FIGURE 7



Energy Wand

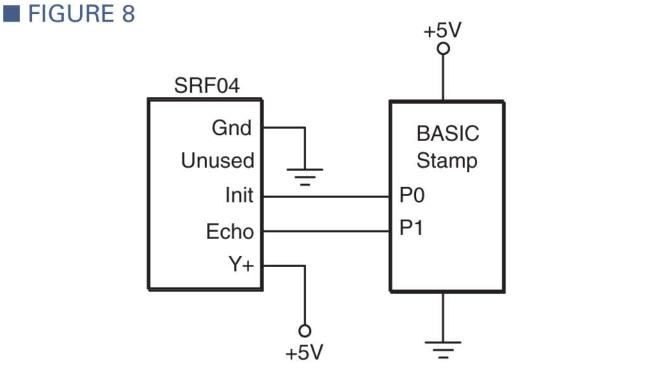


FIGURE 8

Ultrasonic Range Finder

and make the repairs for you at no cost. But if you're like me, I want to know what's happening in my own home. So here's what I've devised — the "Energy Wand" (Figure 7). The wand uses a sensor that measures the air flow inside the room. Specifically, cold air coming in and warm air going out. By passing the wand over windows, doors, and electrical boxes, you can find out where the energy leakage is and how much. The bigger the "hole," the faster the air flows.

Back in July '06, I showed our readers how current mirrors work. At that time, I stressed that the paired transistors are extremely sensitive to variations between the two devices and that they must be matched in every respect, including gain, leakage — and ambient temperature. While this is a problem when working with differential amplifiers, it's a solution to your request. In Figure 7, you will notice that the wand consists of a pair of 2N2222A transistors configured in a current mirror. The transistors are biased so that they generate a tiny bit of heat when operating. That is, they are hotter than the surrounding air. When air flows across Q1, the transistor cools and its parameters change, causing a shift in its collector voltage. The output of the differential pair is amplified by an LMC662 op-amp that drives a frequency-modulated 555 audio oscillator.

The transistors are physically separated, with Q2 mounted inside the project cabinet and Q1 mounted on a "probe" that you can run along the walls and floor. Although I built the prototype using TO-92 plastic transistors, I recommend you use their surface amount equivalent (like the MMBT2222A) for faster response time. I also recommend adding a heatsink to Q2 to stabilize it as much as possible. An alligator-type heatsink clip will work just fine. Four AA cells will power the wand for several hours.

To use the probe, adjust the Zero potentiometer until you hear a sound

MAILBAG

Dear TJ,

On the subject of dealing with the bounce of mechanical switches ... you can choose a switch with a Form C (break-make) contact working into a set-reset latch (or D flip-flop), thus eliminating any need for RC timing (Figure 9). It is only necessary to assure that the moving spring does not bounce far enough to recontact the spring it just left.

— John S. Young
Scottsdale, AZ

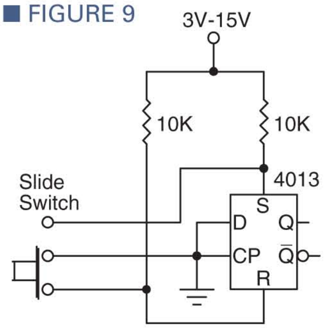
Dear TJ,

Tsk, tsk, I must take you to task on your reply to Judy May (September '06) on contact de-bouncing circuits. The first three circuits show the switch shorting out a capacitor. This is a dangerous thing to do. First of all, many modern switches have gold-flashed contacts or other characteristics which make them very sensitive to high current pulses. Since these circuits short out a capacitor with every closure, the switches are subjected to tremendous (if very short) current surges. A reed switch, for example, is typically rated to shunt a maximum capacitance of .01 µF.

I have attached two improved debouncing circuits (Figure 10). Figure 10a employs a Schmitt trigger and a suitable time constant to provide the necessary hysteresis. In addition, resistor R1 provides filtering which prevents a false output when the switch is released. Note that resistor R1 should be selected to provide adequate current through the switch for reliable operation. The circuit in 10b is the traditional RS flip-flop configuration which reliably eliminates contact bounce. However, it requires a double-throw switch, which is often inconvenient.

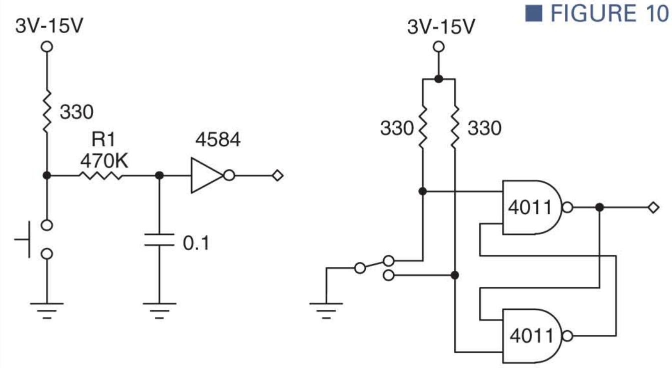
— Larry Sears
Dept. of Electrical Engineering
and Computer Science
Case Western Reserve University

FIGURE 9



Bounceless Slide Switch

FIGURE 10



(a) Schmitt **(b) RS Flip-Flop**

from the speaker. Touch your finger to the Sensor transistor (Q1) and listen for a frequency shift. Set everything aside and let the circuit stabilize for a few minutes. Again, adjust the Zero control until you hear an audio tone and start searching for leaking air. As you roam around the room, the two transistors will drift apart, causing you to frequently touch up the Zero setting. An abrupt change in frequency indicates an air leak.

SONIC SNOW MONITOR

Q I guess my fascination with snow began at an early age when I was growing up in New York City. Back then, I thought the color of snow was grayish black. It was not until I went to college in New Hampshire that I realized snow was white. Which brings me to the present. I would like to get rid of my six-foot pole and replace it with a high-tech solution. The ultimate solution would be a wireless snow sensor with digital readout. Design goal is simple: keep it under $200. I have decided on two possibilities: ultrasound to measure the exact height above a reference point, the other involves a microwave Doppler shift and sensor that triggers below 32 degrees. Or, can I simply buy a high-tech snow sensor within my budget which is what I tried to do in the first place!?!

— Howard Epstein

A My kids have a boogie board that they use for both sea and ski, and they tell me that they can determine the depth of the snow by the size of the rocks the board encounters. On a more practical note, Alaska is replacing their snow poles with ultrasonic range finders like the Devantech SRF04 and SRF05 (list price $25 from **www.acroname.com/robotics/parts/c_Sensors.html**), adopted by many robotics hobbyists. And you can do the same for under $100.

The SRF04 works by transmitting a burst of ultrasonic sound at a target, then listening for a return echo that bounces off the target. Sound travels at about one foot per millisecond, so by counting the number of milliseconds between the transmitted pulse and the received echo, you can calculate the distance to the target. To use this for measuring the depth of snow, mount the SRF04 assembly atop your present snow pole (or fabricate some kind of high-tech housing for your gadget, taking care to insulate it from the ravages of rain and the elements) with the transducers facing the ground. The maximum range of the SRF04 and SRF05 are 10 and 12 feet, respectively.

Just before the first snow fall, take a reading of the distance between the ranger and the ground and make a note of it. You will need this number for future calculations. After your irst measurable storm, fire up the SRF04 again and take another distance reading. This time the distance will be from the ranger to the top of the snow pack. By subtracting that distance from your original distance to the ground, you will arrive at a snow depth.

Fortunately, the SRF04 connects to a microcontroller — like a BASIC Stamp II or PICAXE — via an I^2C serial port. Which means you can throw away your hand calculator and let the microcontroller do the math for you. The wiring is easy and straightforward (Figure 8). Although the completed project is too big to fit into this column, you'll find everything you need for an ultrasonic BASIC Stamp II "snow pole" at **www.acroname.com/robotics/info/examples/srf04-1/srf04-1.html**. **NV**

COOL WEBSITES

LC filter calculators/design

www.geocities.com/gregsdownloadpage/filter.html

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http://nl.internet.com/ct.html?rtr=on&s=1,2oca,1,7mak,l6lp,3qmh,cu1s

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Super bright LED's!

The fragile glass Xenon tube is gone, replaced with high intensity LED's! Variable flash rate and built-in audio trigger input to sync to your audio. Optional display boards available. Runs on 12VDC or use our AC125 PS.

LEDS1C LED Strobe Kit 44.95

Personal Guitar Amp

Brand New, Popular Choice!

The new PGA1 allows you to practice both your regular and base guitars in peace! Also works as a great DI to feed your home stereo amplifier! CD/MP3 input allows you to play to your favorite music. Includes case shown!

PGA1 Guitar Amp Kit 64.95

ECG Heart Monitor

Check your own heart!

Provides a visible and audible display of your heart rhythm! Variable gain, bright "beat" LED, and monitor output for display on your scope. Just like the lab! Reusable sensors are included. Runs on a safe 9VDC battery.

ECG1C ECG/EKG Kit 44.95

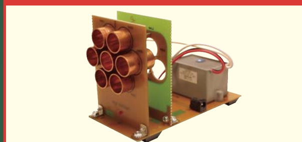
Plasma Generator

Generate 2" sparks!

Produces a stunning and shocking 25kV at 20kHz from a solid state circuit! Build your own plasma bulbs, light fluorescent tubes without wires and more! A great learning kit. Runs on 16VAC, order our PS21 power supply.

PG13 Plasma Gen Kit 64.95

HV Ion Generator



Make a blast of fresh air!

Generates a steady state DC voltage at constant non-pulsed current at 7.5kV DC negative, 400uA. That's a LOT of ions! Learn how modern spacecraft use ions to accelerate through space. Runs on 12VDC or our AC125 PS.

IG7 Ion Gen Kit 64.95

20W SubMini Audio Amp

20 watts and no heat!

Delivers a super clean 20W output from one SMT package! Ultra efficient class D design produces no heat. PCB can be snapped into a small circle for special applications. Runs on 18VDC for rated output, use our SPS18 PS.

UAM2 20W SMT Amp Kit 34.95

Digital Voice Storage

Multiple message storage!

The *Bullshooter-II* provides up to 8 minutes of digital voice storage that can be broken down into 8 separate stored messages! Great for announcements, etc. Built-in mic plus external input. Runs on 12VDC or our AC125 PS.

BS2C Bullshooter-II Kit 69.95

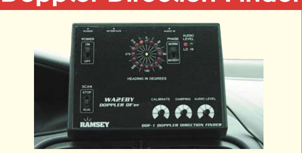
Speed Radar Gun

Now YOU can be the cop!

Our famous *Speedy* radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. 1/8th mile range is typical. You supply two coffee cans! Runs on 12VDC or our AC125 power supply.

SG7 Speedy Radar Kit 59.95

Doppler Direction Finder



Find that transmitter quick!

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

DDF1 Dir. Finder Kit 169.95

Touch-Tone Reader

Read the number dialed!

The *Tone Grabber* captures dialed phone numbers, repeater codes, control codes, or anything that uses touch-tone signaling. Flash micro stores 640 digits! Phone line and audio inputs. Runs on 12VDC or our AC125 PS.

TG2C Tone Grabber Kit 69.95

Signal Magnet Antenna

Pulls in distant stations!

Super Hi-Q ferrite rod antenna with Faraday shield eliminates noise from power lines, dimmers, static and more! Great results from 500kHz to 15MHz. Super for AM broadcast band! Includes power supply.

SM100 Sig Magnet Kit 89.95

Did You Know...

- ✔ *It's impossible to give you full specs on these products in a 1" space!*
- ✔ *A lot of our kits are also available "factory assembled and tested", if you don't want to build it!*
- ✔ *We have over 350 products currently available, and all those don't fit here!*

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Mini-Kits... Holiday Themes!

LED Animated Santa

Animated Santa and reindeer display has 126 dazzling colored LEDs! Makes a great holiday sign! Animated motion makes it come alive. Runs on standard 9V battery or external power supply.

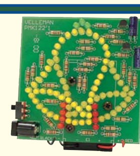
MK116 LED Santa Kit $19.95

LED Christmas Tree

Electronic Christmas tree features 134 bright colored LEDs in the shape of a tree with 18 random flashing blinking "candles"! Runs on a 9V battery or PS.

MK117 LED Christmas Tree Kit $17.95

LED Animated Bell



This holiday bell is animated to simulate swinging back and forth! 84 bright colored LEDs will dazzle you with holiday cheer! Includes an on/off switch. Runs on 9V.

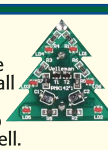
MK122 LED Bell Display Kit $13.95

3D LED Christmas Tree

Not your average LED display! 4 branch sections give this tree a 3D look! 16 red LEDs light it up with yellow LED's for you to customize your tree! 9V battery base.

MK130 3D LED Tree Kit $7.95

SMT LED Christmas Tree



Build this subminiature Christmas tree and learn SMT at the same time. Small enough to wear as a badge or pendant! Extra SMT parts are included so you can't go wrong! Runs on Li-Ion cell.

MK142 SMT LED Tree Kit $8.95

SMT LED Smiley Face

This is a great attention grabber and also teaches you the basics of SMT construction! Display your "smiley" as a pin or badge! Extra parts included!

MK141 SMT LED Smily Kit $8.95

LED Traffic Signal

Impress your friends with this neat 4-way traffic signal! Operates just like a standard signal, and features adjustable delay. Red, yellow, and green LEDs are used just like the real thing! Runs on 9V battery.

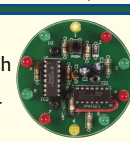
MK131 LED Traffic Signal Kit $7.95

Stereo Super Ear

The stereo Super Ear features an ultra high gain audio amp with two sensitive microphones! Boosts audio 50 times! Includes volume control. Runs on 3 AAA batteries.

MK136 Stereo Super Ear Kit $9.95

Wheel Of Fortune



Just like the casino game! Just push the button and the LEDs "rotate" and slowly come to a stop, displaying the "winner"! Push it again to start over. Runs on 9V battery.

MK152 Wheel Of Fortune Kit $7.95

RF Preamplifier

Super broadband preamp from 100 KHz to 1000 MHz! Gain is greater than 20dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 RF Preamp Kit $19.95

Light Sensitive Switch

Senses light to turn your device on at night, off at dawn! Provides a NO/NC 5A relay contact. Adjustable delay. Runs on 12VDC.

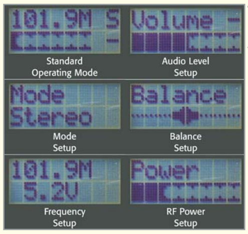
MK125 Light Sens. Switch Kit $7.95

FM Broadcasters
Fun Stuff For The Holidays!

Digital FM Stereo Transmitters

- ✔ **Rock stable PLL synthesized**
- ✔ **Front panel digital control and display of all parameters!**
- ✔ **Professional metal case**
- ✔ **Super audio quality!**
- ✔ **25mW and 1W models!**

For nearly a decade we've been the leader in hobbyist FM radio transmitters. Now for 2005 we introduce our brand new FM30 series of FM Stereo Transmitters! We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!



The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit, with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version, with 1W output for our export market! Both are designed around an RF tight vinyl clad metal enclosure for noise free and interference free operation. All settings are done through the front panel digital control and LCD display! All settings are stored in non-volatile memory for future use.

Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC plug-in power supply. The stylish black metal case measures 5.55"W x 6.45"D x 1.5"H. *(Note: The end user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US).*

FM30B	**Digital FM Stereo Transmitter Kit, 0-25mW, Black**	**$199.95**
FM35BWT	**Digital FM Stereo Transmitter, Assembled, 1W, Black**	**$299.95**

Professional Synthesized Stereo FM Transmitter

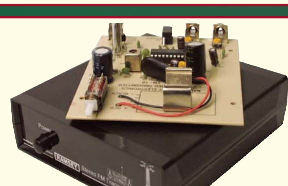
- ✔ **Fully synthesized 88-108 MHz for no frequency drift**
- ✔ **Line level inputs and output**
- ✔ **All new design using SMT technology**

Need professional quality features but can't justify the cost of a commercial FM exciter? The FM25B is the answer!

A cut above the rest, the FM25B features a PIC microprocessor for easy frequency programming without the need for look-up tables or complicated formulas! The transmit frequency is easily set using DIP switches; no need for tuning coils or "tweaking" to work with today's "digital" receivers. Frequency drift is a thing of the past with PLL control making your signal rock solid all the time - just like commercial stations. Kit comes complete with case set, whip antenna, 120 VAC power adapter, 1/8" Stereo to RCA patch cable, easy assembly instructions, and the SMT parts are factory preassembled - you'll be on the air quick!

FM25B	**Professional Synthesized FM Stereo Transmitter Kit**	**$139.95**

Tunable FM Stereo Transmitter



- ✔ **Tunable throughout the FM band, 88-108 MHz**
- ✔ **Settable pre-emphasis 50 or 75 µSec for worldwide operation**
- ✔ **Line level inputs with RCA connectors**

The FM10C has plenty of power to cover your home, back yard, or city block. You'll be amazed at the exceptional audio quality of the FM10C. Tunes through the entire 88-108MHz band. Re-broadcast your favorite music commercial free and with the dynamic range the musician intended, without all that nasty compression the big boys use to make their station sound louder than the competition. Compression produces a noticeably muddier and less dynamic sound. Runs on an internal 9VDC battery, external 5-15VDC, or our FMAC AC power adapter.

FM10C	**Tunable FM Stereo Transmitter Kit**	**$44.95**
FMAC	**110VAC Power Supply for FM10C**	**$9.95**

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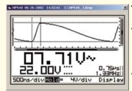
Hand Held Digital Scope With DVM Readout

- ✔ **Digital waveform and measurement display!**
- ✔ **10MHz and 40MHz sample rates!**
- ✔ **Backlit LCD display**
- ✔ **RS232 output (40MHz model only)**
- ✔ **Charger, case, probes included**

We've seen a lot of portable scopes and scope/meters, and we've also seen the price tags! They have always been way out of the reach and budget of the hobbyist. No more! Now for close to the price of a good DMM you can have a personal scope that also has DVM readout for dBm, dBV, DC, and True RMS! Frequency readout is also displayed on the screen through markers, plus the scopes have two memories for digital storage.



The 40MHz model also includes an RS232 output and serial interface to capture the screen display on your scope to your PC at the mere push of a button! These scopes run on 5 standard AA Alkaline batteries (not included) which provide up to 20 hours of use. You can also use rechargable AA NiMH batteries instead and they'll be charged with the optional power supply. Both units come with a custom foam lined high impact carrying case, set of high quality scope probes, AC power adapter and a comprehensive user's manual. If you're working with electronic circuits, automotive applications, audio and stereo applications or other applications, the personal scope is for you...at a price that can't be beat!

HPS10SE	**Personal Handheld 10MHz Digital Scope**	**$229.95**
HPS40	**Personal Handheld 40MHz Digital Scope w/RS232**	**$299.95**

Audio/RF DDS Signal Generator

- ✔ **DDS and SMT technology!**
- ✔ **Frequency range 0 Hz to 5 MHz with 0.1Hz resolution!**
- ✔ **0 to 10V peak to peak output level**
- ✔ **Sine, Square, or Triangle waveform output!**
- ✔ **Non-volatile memory**
- ✔ **Factory assembled and tested**

DC to 5 MHz...In 0.1 Hz Steps!

Following in the footsteps of our world famous SG550, we are proud to introduce the SG560, the next generation signal generator!

To begin with we increased the frequency range all the way up to 5MHz and all the way down to 0Hz (yes, we mean zero...or DC!) in continuous 0.1Hz steps across the entire range! Then we gave it a variable output level all the way up to 10V peak to peak in either Sine, Square, or Triangle waveforms! You can also provide a DC offset to the output to recreate TTL, 4000 series logic levels, low voltage logic levels, AC waveforms with a DC component, or just plain AC signals!

The SG560 contains a 10 bit DDS and filtering for a low noise, accurate low distortion output. The output stage utilizes the latest technology in digital modems and high power, high bandwidth DSL modems and is capable of a direct output of 2.5W! You can even generate carrier signals in the AM band for testing AM receivers and circuits. A jumper option for zero ohm output impedance allows for true output terminal metering. But watch out, 2.5 watts is enough to damage incorrectly connected circuits!

Surface mount technology is used throughout the SG560 making it extremely reliable and accurate. Frequency is entered directly on the sealed membrane keyboard and adjusted with a precision rotary encoder with an oversized knob. Both frequency and output level are displayed on a high contrast, two-line LCD display.

The SG560 operates on 8 to 16VDC and includes a standard 110VAC power adapter. Because of the surface mount design the SG560 is only available factory wired and tested. If you are looking for a lab quality signal generator at a super price, the new generation SG560 fits the bill... and a whole lot more!

SG560WT	**Audio/RF Signal Generator, Factory Assembled**	**$329.95**

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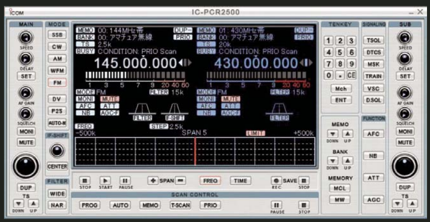
- ***Enjoy It!***

*Buy a PCR2500 or R2500 and get a UT-122 module with P25 capabilities!**

PCR2500

PC CONTROLLED DUAL BAND, DUALWATCH DIGITAL MODE RECEIVER.



- Dual Receiver
- 0.01 to 3299.999 MHz (Main), 50 to 1300 MHz (Sub)**
  Main Receiver: AM, FM, WFM, SSB, CW, DV and P25
  Sub Receiver: AM, FM and WFM
- Dual Antenna Ports
- Standard DualWatch
- Dual Receiver Diversity
- Three Operating Screen Options
- D-STAR Compatible (Option UT-118)
- Unlimited Memory Channels
- PCR Digital Record

UT-122 MODULE

PROVIDES APCO P25 DIGITAL MODE RECEPTION.

R2500

DUALWATCH, DIGITAL MODE DIVERSITY RECEIVER.

- Dual Receiver
- 0.01 to 3299.999 MHz (Main), 50 to 1300 MHz (Sub)**
  Main Receiver: AM, FM, WFM, SSB, CW, DV and P25
  Sub Receiver: AM, FM and WFM
- Dual Antenna Ports
- Dual Receiver Diversity
- D-STAR Compatible (Option UT-118)
- Dual Display
- 1000 Memory Channels
- PCR Upgradeable

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NEW PRODUCTS

- HARDWARE
- SOFTWARE
- GADGETS
- TOOLS

PROGRAMMABLE COMPUTER BOARD DEBUTS AT $49

ARMmite, a single board computer programmable from the PC with a USB port, is now available for $49 from Coridium Corp. at **www.coridiumcorp.com**. Raising the standard for delivering value and price, the product offers functionality, performance, and ease-of-use for prototype and low-volume application development. ARMmite target users include:

- Computer professionals in manufacturing and production management.
- Educators and students learning and developing applications.
- Hobbyists exploring and creating solutions.

Performance Advantage

Connecting from the PC using a USB port, the ARMmite enables users to create code using Basic programs. The programming is processed at a rate of more than 10 million instructions per second, and compiled according to ARM instructions, consistently delivering high performance. Basic programs have an available 12K for user code, 5K for variables. In addition to the available Basic, Coridium also provides a pre-configured ANSI C development system, based on GCC.

Features and Benefits

The ARMmite libraries provides support for SP1, 1^2C, 1-Wire, and ASYNC protocols. Users download their programming to the computer board, which has connections for 24 five-volt tolerant digital I/Os shared with eight 10-bit A/D inputs. Control of these I/Os can be updated faster than 1 MHz. During programming or communication with a PC, power is taken from the USB port, or the ARMmite can accept unregulated 7-12V from an optional power transformer. Onboard supplies generate 5V, 3.3V, and 1.8V.

The 50 x 80 mm board includes two square inches of prototype area. The prototype area accepts parts with 0.1 inch pin pitch, DB style connectors, or 3.5 mm terminal blocks. In addition, a 32 KHz oscillator provides accurate timing which can be continuously operated with an optional rechargeable battery. This board is also compatible with the Hammond 1455C801 aluminum enclosure.

For more information, contact:
Coridium Corp.
Tel: **800-478-9020**
Web: **www.coridiumcorp.com**

250 mA LDO

Microchip Technology Inc., a leading provider of microcontroller and analog semiconductors, has announced the MCP1702 Low Dropout Regulator (LDO) — a 250 mA LDO with low quiescent current, high input voltage, over-voltage protection, and thermal shutdown on a single chip. The new LDO is ideal for applications requiring long battery run-times and high tolerance for input-voltage variations, such as smoke detectors, fire alarms, and commercial and residential thermostats.

With a low quiescent current of 2 microamperes (μA), the MCP1702 requires only a small amount of current to maintain regulation, thereby significantly extending battery run times. It supports input voltages up to 13.2V, meaning that standard 9V alkaline batteries can be used to help keep costs low. The MCP1702 LDO also features device- and circuit-protection capabilities such as overcurrent protection and thermal shutdown, enabling users to more effectively avoid system failures. With highly accurate output-voltage regulation — including ±2 percent over-temperature accuracy — the MCP1702 helps to ensure smooth, reliable system operation.

"With the ever-present need for longer battery run-times in battery-powered devices, our customers need LDOs with low quiescent current and high tolerance for input-voltage variations," said Bryan Liddiard, vice president of marketing with Microchip's Analog and Interface Products Division. "The MCP1702 LDO was designed to meet these needs, plus provide additional benefits such as ceramic output-capacitor stability, which helps to reduce design size. With all of these features on one chip, the MCP1702 helps our customers to build in the performance that their designs demand, with minimal board space and low costs."

Applications that can benefit from the MCP1702 LDO include those requiring long battery run-times (smoke detectors, life-support devices); those with high input voltage variations (fire alarms, commercial and residential thermostats); and battery-powered portable devices (personal media players, MP3 players).

Packaging, Pricing, and Availability

Samples of the MCP1702 LDO are now available at **http://sample.microchip.com**, and volume production orders can be placed at **www.microchipdirect.com**. The device is available in small, three-pin SOT-89, SOT-23, and TO-92 packages, all of which provide superior thermal dissipation. It is priced at $.37 each in 10,000-unit quantities for all package types.

For more information, contact:
Microchip Technology, Inc.
Tel: **888-MCU-MCHP**
Web: **www.microchip.com/MCP1702**

A 500 MSa/s PC BASED OSCILLOSCOPE WITH A LARGE DATA BUFFER

Link Instruments now offers the DSO-8502 — an oscilloscope which samples at 500 MSa/s with a 1 Mpt data buffer. The portable, battery-powered DSO-8502 connects to a PC via USB 2.0. The powerful FrontPanel® software is simple to use, and runs on Windows XP, 2000, and Vista.

For over 20 years, Link Instruments has produced high performance instruments of exceptional value. The DSO-8502 is no exception — priced at $950.

With bandwidth exceeding 100 MHz, the DSO-8502 operates at an impressive single shot sampling rate of 500 MSa/s in single channel mode and 250 MSa/s in dual channel mode. A 1 Mpt data buffer is offered in single channel, while the dual channel mode reaches 512 kpts. The large memory buffer allows users to maintain a high sampling rate for a long recording time, thus capturing otherwise elusive events.

"The big buffer really saved me. With my last oscilloscope, I always had to balance recording time and time per division. With Link's scope, I can record at the fast sampling rate and still see the entire event," comments Bob Mitchell, a consultant and beta tester.

The software provided with the DSO-8502 oscilloscope has a single operating screen that displays the waveforms and all setup controls in easy-to-use menus. The unit also offers advanced features like automatic measurements, advanced triggering modes, FFT spectrum analysis, and pass/fail testing. Advanced trigger modes include pulse width, pulse count, combined pulse width and count, and a new pulse width window mode which triggers on pulses within a given range.

Included with the DSO-8502 are two 100 MHz bandwidth switchable 1x/10x probes. Another feature of the unit is its small size (7" x 3.5" x 1.5") which makes it very portable. It can be run with the included power adapter or by four AA batteries. Consequently, it does not drain your laptop battery when wall power is not available.

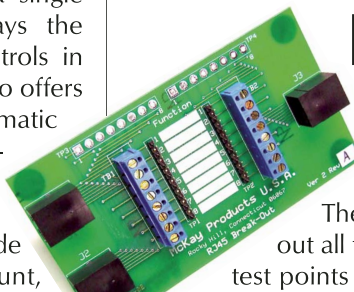
As with all of Link Instruments products, there are numerous advantages for using PC based instruments. PCs offer a large color display that is typically found only in expensive standalone instruments. Links' software lets you take advantage of dual and triple screen PCs by having the waveform spanning all screens. Also, PC-based tools lower cost by taking advantage of your PC's resources. The DSO-8502 continues the tradition of Links' PC-based test equipment which began in 1986.

Pricing and Availability

The DSO-8502 has a list price of $950. Price includes DSO-8502 main unit, software, 100 MHz bandwidth switchable 1x/10x passive probes, USB cable, and AC adapter. Product is available for immediate delivery.

For more information, contact:
Link Instruments, Inc.
Tel: **973-808-8990**
Email: **sales@linkinstruments.com**
Web: **www.linkinstruments.com**

THE RJ45-BOB



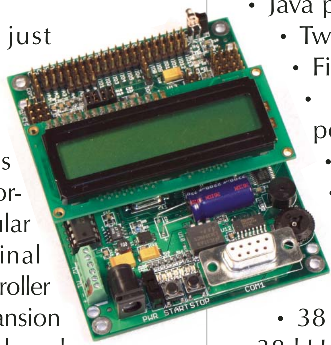
McKay Products USA announces the release of their RJ45 Break-Out Box, RJ45-BOB. The RJ45-BOB brings out all the connections to test points and binding posts for the now common RJ45 connector found on late-model mobile and amateur radios, Ethernet, serial cables, T1 lines, and a host of other interface applications. Features include:

- Gold plated test points.
- Binding post connections.
- Convenient solder points for connection to custom test equipment.
- Label area for each RJ45 pin.
- One side has two RJ45s in a "Loop Thru" configuration.
- Other side has one RJ45 as a "Dead End" configuration.

MSRP $34.95 each, quantity discounts available.

For more information, contact:
McKay Products USA
38 New Britain Ave.
Rocky Hill, CT 06067
Tel: **860-808-1280**
Fax: **860-721-1583**
Web: **www.mckayproducts.com**

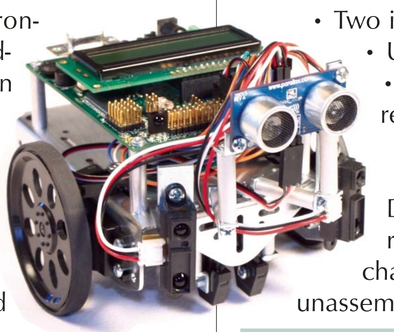
THE INTELLIBRAIN™ 2 ROBOTICS CONTROLLER



RidgeSoft has just released the IntelliBrain™2 robotics controller — its second generation robotics controller — which incorporates the most popular features of the original IntelliBrain robotics controller and the IntelliBrain expansion board on a single circuit board. RidgeSoft has also updated the IntelliBrain-Bot Deluxe educational robot to include the IntelliBrain 2 robotics controller and an ultrasonic range sensor.

The IntelliBrain 2 robotics controller is designed specifically for educational robotics applications. Students program their robots using true Java™ programming — not a Java-like language or other esoteric programming language. Tutorials and a course outline — which are available online — facilitate easy integration into computer science or engineering curriculum.

The RoboJDE™ robotics software development environment, which is included with the IntelliBrain 2 robotics controller, includes dozens of example programs and tutorials covering everything from basic sensing to programming advanced robotic intelligence.



The IntelliBrain 2 robotics controller's design makes it easy to interface with many popular sensors and effectors including hobby servos, DC motors, infrared sensors, sonar sensors, wheel encoders, vision sensors, compasses, GPS devices, speech synthesizers, and many more.

The robotics class library included with RoboJDE provides an easy-to-use, object-oriented programming interface to all of the IntelliBrain 2 controller's features, as well as software support for many sensors and effectors, and an assortment of robotics classes to provide a foundation for programming intelligent robots.

The IntelliBrain 2 robotics controller includes the following features:

- Java programmable
- Two DC motor ports
- Five servo ports
- Seven analog/digital input ports
- 13 digital input/output ports
- Two RS232 serial ports
- Five I²C ports
- Six program-controlled LEDs
- 38 kHz infrared transmitter
- 38 kHz infrared receiver
- 16 x 2 LCD display buzzer thumbwheel
- Two pushbuttons
- Atmel ATmega128 CPU
- 132 KB RAM
- 128 KB Flash
- 4 KB EEPROM

The IntelliBrain-Bot Deluxe educational robot includes:

- IntelliBrain 2 robotics controller
- Two servo motors
- Two wheel encoder sensors
- Two line sensors
- Two infrared range sensors
- Ultrasonic range sensor
- Chassis, wheels, and required hardware

The IntelliBrain-Bot Deluxe educational robot kit can be purchased either assembled or unassembled.

For more information, contact:
RidgeSoft, LLC
PO Box 482
Pleasanton, CA 94566
Email: **info@ridgesoft.com**
Web: **www.ridgesoft.com**

HIGH PERFORMANCE, COST-EFFECTIVE, DMMs

Two new, cost- effective digital multimeters incorporating a host of high performance features have been introduced by Protek Test and Measurement, a division of Intelient Technologies, Inc.

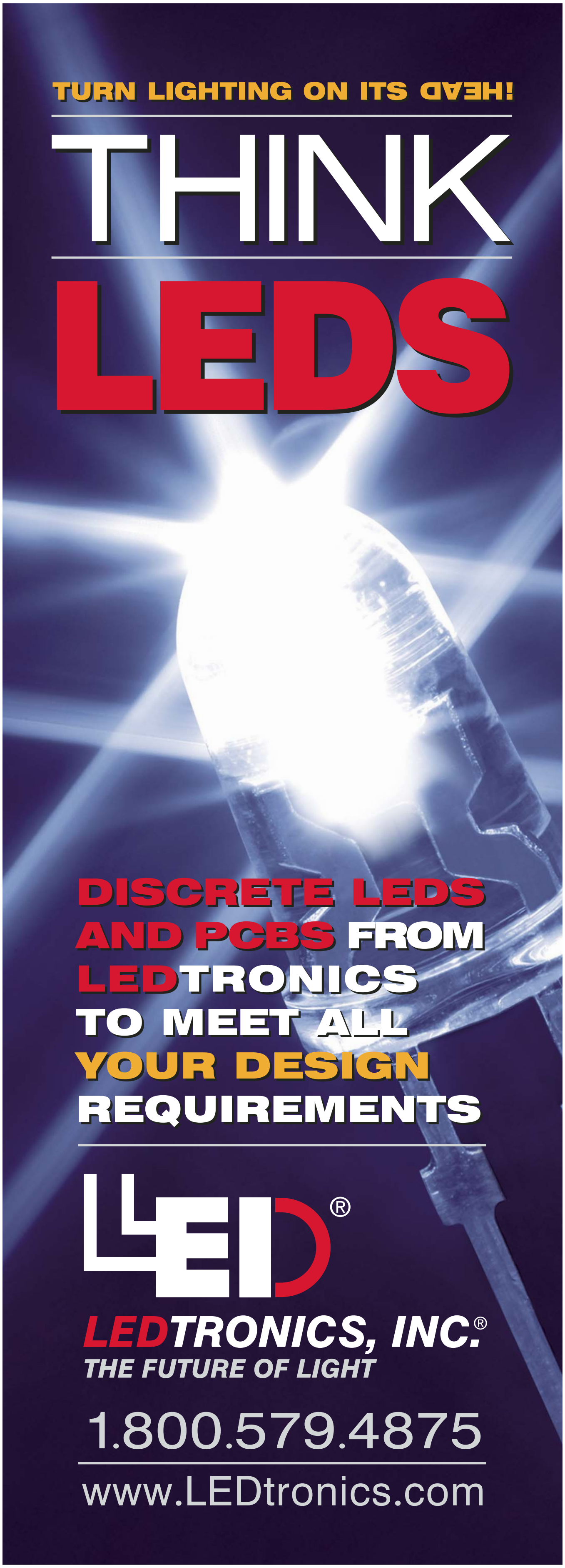
The new entries consist of the 80,000 count, dual display Model 6800, priced at $194. With a basic DC accuracy of ±0.05%, the unit features a 3V, 5 Hz to 5 kHz square wave generator, a duty cycle measurement, plus RPM capability constitute some of its many functions. The companion 50,000 count Model 6500, priced at $173, features a 50 segment bar graph backlit display, basic DC accuracy of ±0.03%, and RS232 interface with software and cable.

Some of the key measurement features of the True RMS Model 6800 are: frequency, pulse width, duty cycle, Hi/Lo limit testing, dBm level (relative to 20 reference impedances), Min/Max/Avg, as well as peak hold and relative modes. The unit has a built-in 10 hour timer and is complete with RS232 port, software, and cable. The 6800 meets CE, Category II 1,000V and Cat III 600V standards. The product package incorporates a holster, test leads, temperature probe, 9V battery, RS232 software with cable, plus instruction manual.

The 50,000 count Model 6500 includes dBm measurement (40 ohms to 1,200 ohms references), AC and AC + DC True RMS, frequency, duty cycle, capacitance, plus Min/Max/Relative modes. The unit meets Category III 1,000V standards and includes auto power off. The 6500 is complete with manual, test leads, and RS232 software with cable.

For more information, contact:
Protek Test and Measurement
Web: **www.protektest.com**

Continued on Page 69



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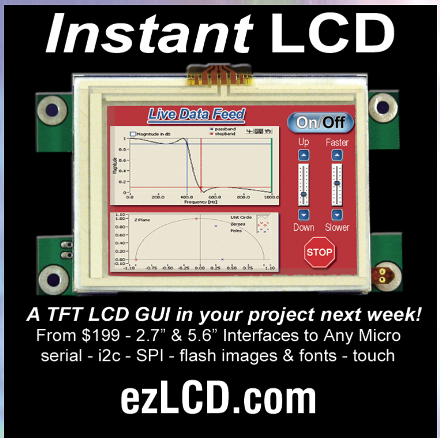

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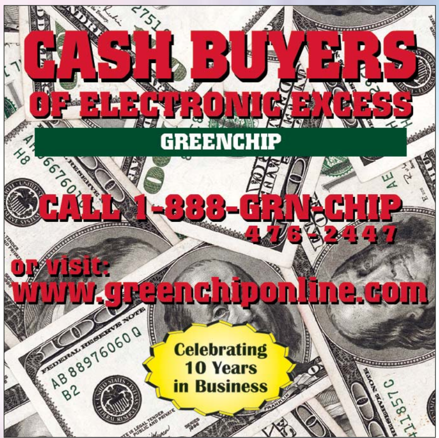

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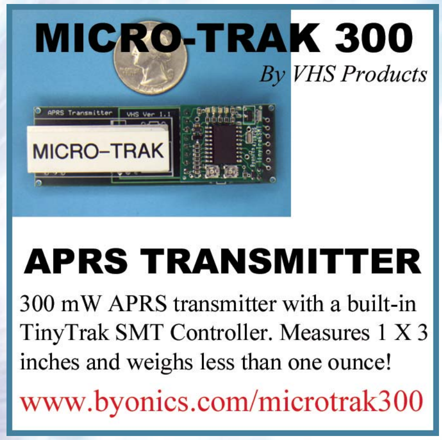

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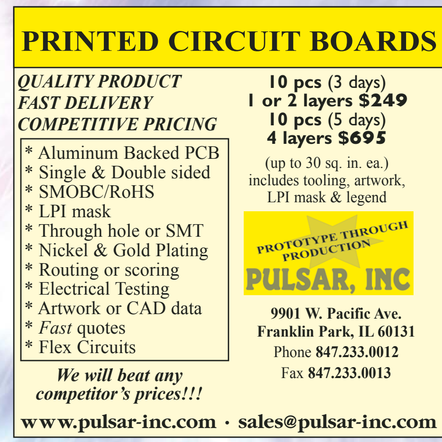

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So, don't throw out that junk you're not using — it may be just what a budding electronics hobbyist needs to get that project finished!

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THIS MONTH'S PROJECTS

LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

●○○○ . . . . Beginner Level

●●○○ . . . . Intermediate Level

●●●○ . . . . Advanced Level

●●●● . . . . Professional Level

How about handing her a Valentine's Day present that contains

a raised heart surrounded by a bright red halo and plays *Let Me Call You Sweetheart* at the same time,

or giving your favorite person a birthday gift wrapped in ribbons of blue electroluminescent wire with a lit LED panel name tag. An anniversary gift wrapped in silver paper and covered with 18 illuminated white tea roses is sure to please, as is a Christmas present enclosed in a seasonal tin adorned with a wreath of lights.

OPTOELECTRONIC GIFT WRAPPING

Show that special someone that you care "electronically" by presenting them with gifts in wrappings that literally "glow."

In general, any battery driven illumination source can be used to decorate a package. The on/off switch can be external, or internal accompanying the power supply.

One end of the gift wrapped box needs to be able to be opened in order to insert a present, and in order to access an internal switch, if needed, to power up the package.

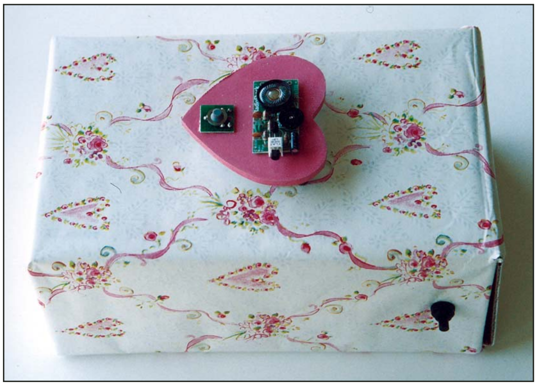


FIGURE 1. The Valentine's Day gift is shown from the side with the external power switch visible near the flap that opens at one end of the box.

Valentine's Day Gift

Figures 1 and 2 show the heart of this project (pun intended). A small, roughly 3-1/2 inches across, wood heart obtained from a crafts store was painted pink (top) and white (bottom), and then cemented to three 1/2-inch long Bakelite standoffs. A one watt, ultra-ultra bright red LED (**www.allelectronics.com**; CAT# LED-109) was attached to the center of the package using glue. The two wires from the LED were fed through holes to the inside of the box and attached to

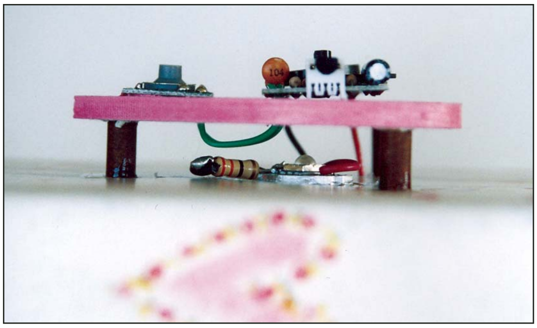
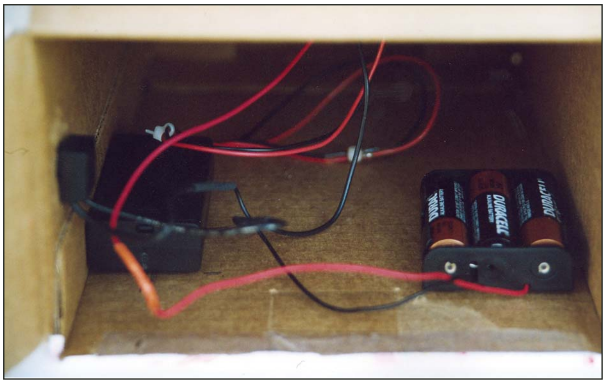


FIGURE 2. Details of the mounted heart can be seen in this side view closeup.

BY J. RONALD and LYNNE R. EYTON



■ FIGURE 3. One end of the Valentine's Day gift box can be opened to put in batteries and insert a present (after bending the wires out of the way).

a 4.5 volt power supply (three AA batteries). A one watt, 33 ohm dropping resistor wired in series with the batteries was used to reduce the brightness. A push on/push off switch (**www.allelectronics.com**; CAT# PB-21) attached through the side of the box allows the gift giver to turn on the LED just before the present is presented.

The paper gift wrapping on one end of the box was carefully cut so that a flap can be opened and closed. After cutting the gift wrapping and cardboard box to create a flap, the paper needs to be completely taped to each edge of the box to prevent tearing and fraying. The flap access allows the interior of the box to be wired (see Figure 3), allows for the insertion of batteries, and allows for enclosing the contents of the gift. The wires shown in Figure 3 can be bent to one side to accomplish all of this.

The heart/standoffs assembly was then glued in place over the red LED. A RadioShack Prewired Musical Song Player (Catalog # 276-720 and available online at **www.radioshack.com** for $1.47!) was added to the top of the wood heart. The unit comes in three parts: the electronics board/speaker, a tactile switch, and a two AA battery power supply. One of the five song chips (*Let Me Call You Sweetheart*) was used for this project. The tactile switch and the music board were glued to the top of the heart; the battery power supply was fastened to the inside of the box using a Velcro strip.

Turn on the red LED heart, start the music, and make your presentation. Figure 4 shows only a poor facsimile of the real world result. No matter how many different photos I took of the illuminated heart using both film and digital cameras, not one was able to correctly capture the bright red halo surrounding the heart and the soft red wash covering the entire top of the package at the same time.

Birthday Gift

The electroluminescent (EL) wire used to wrap the present shown in Figure 5 was obtained from an auto parts store (*Stringlight* made by Quest Industries, Inc., is a five foot blue EL wire used for accenting the interior of cars). An equivalent product can be obtained from **www.allelectronics.com** as CAT#

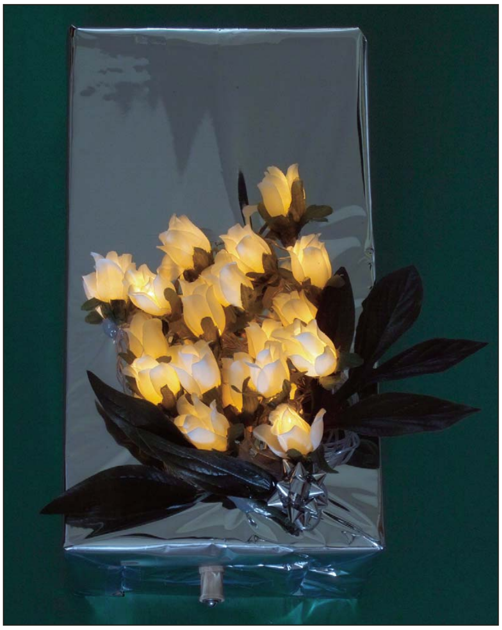
■ FIGURE 4. The Valentine's Day gift box with the red LED under the heart turned on.

■ FIGURE 5. The birthday gift wrapped box is shown with a blue EL wire ribbon and an LED backlight panel name tag.

■ FIGURE 6. A "turned-on" birthday gift wrapped package with glowing blue EL wire and a green backlit name tag.

■ FIGURE 7. Silver paper wrapping and 18 white silk flower tea roses were used to create this anniversary gift box.

■ FIGURE 8. The components needed to make the illuminated flowers are shown in this figure with the 1.5 volt grain-o-wheat bulb and a silk tea rose in the top half of the image. The disconnected flower parts spaced along the light bulb wires and a completed illuminated flower are shown in the bottom half of the image. A shot of hot melt glue was used to keep all the parts pressed up against the light bulb.



■ FIGURE 9. All 18 roses are lit up in this image of the anniversary gift box.

■ FIGURE 10. Two Christmas tins are decorated with short strings of 10 lights. On the left the lights are intertwined in a small silver colored pine needle and pinecone wreath glued to the tin lid, and on the right nine of the 10 lights have been inserted through holes spaced around and in the middle of the tin lid; the green plastic stars were then press-fitted to the top of each protruding lightbulb.

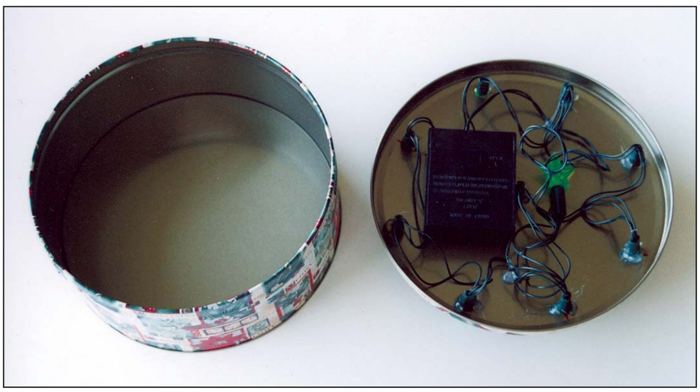
EL-1B and consists of 1.5 m (4.92 ft) of blue EL wire and a driver that operates on two AA cells. The name tag shown in Figure 5 was made from an LED backlight panel (roughly 4-1/2 inches by 1-1/4 inches) that is no longer available. A good substitute is a **www.jameco.com** 2.05 inches by 0.78 inches backlight, diffused LED panel (Part Number 151415CK), or **www.goldmine-elec.com** large (6-3/8 inches by 7/8 inches) backlight panel (Item Number: G14880). Because the wire is wrapped both ways around the package, only one half of one end was constructed as a flap that can be opened to insert a gift, and then opened again just before a presentation to switch on the EL wire driver and LED panel tag. Again (see Figure 6) conventional or digital photography was not able to completely capture the naked eye visible brightness of this illuminated present.

Anniversary Gift

The 18 white tea roses adorning the silver paper wrapped box (Figure 7) are silk flowers that can be obtained from any crafts store. Each flower was taken apart by removing the stem and then putting it back together again with the two wires attached to a grain-o-wheat light bulb acting as the new stem; Figure 8 shows the components and the process for reconfiguring each flower.

The grain-o-wheat light bulbs

■ FIGURE 11. Battery pack and the 10 plain lights string.



■ FIGURE 12. This picture shows the inside of the tin top with the battery pack glued in place; nine of the 10 star lights were inserted through holes around and in the middle of the tin. The 10th light (with green star) was glued down next to the battery pack.

■ FIGURE 13. These images show both Christmas tins with their lights on.

■ FIGURE 15. This push off (left)/push on (right) star light package should be suitable for a baby shower gift, a graduation gift, or an accomplishment gift.

■ FIGURE 14. This push off (top)/push on (bottom) heart light package should be suitable for a Valentine's Day gift, an anniversary gift, or a birthday gift.

are available from many electronic surplus outlets with the 1.5 volt ones shown in Figure 8 obtained from **www.mpja.com** (Stock # 8980-LA). A small flap (with a wooden dowel handle) was cut from one end of the box to facilitate entry for inserting a gift and switching on the 1.5 volt battery supply. The flowers and accompanying greens were attached to the surface of the present with hot melt glue. The softly glowing flowers make a spectacular presentation (see Figure 9).

Christmas Gift

Round (and square) Christmas tins decorated for the season are usually available from all sorts of general merchandise stores and food markets during the holidays. These are excellent containers that allow for an easy conversion to illuminated gift packaging. Figure 10 shows two possibilities using short, two C battery driven, strings of 10 Christmas tree lights (Figure 11) that I obtained from a discount store. They are available around Christmas time as a plain 10 light set (Item # ES62-105A) and as a set of 10 lights with green plastic stars attached (Item#

■ FIGURE 16. This push off (left)/push on (right) happy face light package should be suitable for any occasion. Hey, what can you say about the omnipresent smiley symbol — such wrappings should go to a happy person for whatever reason!

D43985). The plain set of 10 lights are also available online from several vendors including **www.offthedeepend.com** (Item# SL232 — Battery Miniature Light Set) and **www.bettyschristmashouse.com** (Battery Light Set).

I used the plain set of 10 lights to illuminate a small Christmas wreath (actually a three inch candle wring found at a local card shop). The battery pack (which has an onboard on/off switch) was glued to the inside of the tin top. A slightly different arrangement was used for the second tin (see Figure 12). Nine of the 10 lights were used on the outside of the tin top (eight around the periphery and one in the middle) by drilling holes through the tin, inserting the light bulbs only through the holes, and then attaching the plastic stars to the top of the lights to hold them in place. The 10th light was glued to the inside of the tin top along with the battery pack and switch. Figure 13 shows both tins illuminated; the actual (non-photographic) visual experience is much more pleasing.

An Easy Alternative

If all of this seems to be too much fuss for creating illuminated gift packages, there is a quick, simple, and inexpensive option for accomplishing the same goal, albeit with somewhat less elegance. I obtained the push on/push off four AA battery driven auxiliary lighting units shown in Figures 14, 15, and 16 at a Dollar Store. Glued to the center of an appropriately gift wrapped box, they make for an unusual and bright presentation. Because the illumination is so intense, I used a jumper wire in the battery holder to reduce the number of AA battery cells used from four to three. Whichever way you decide to create packages that light up, you will be surprised at the delighted reactions from recipients of presents that glow. **NV**

Something interesting happened in the ice storm of 1998, and again during the great blizzard last winter, in many new homes throughout New England and as far south as Atlanta.

Many families were forced to leave their homes when the electrical power went out,

even though they had perfectly functional furnace systems.

FURNACE BACKUP

The reality is that builders are now constructing new homes without functional fireplaces because they are considered decorative instead of functional. In homes where decorative fireplaces are installed, they are incapable of being heated; instead these non-vented fireplaces burn only small quantities of natural gas under ceramic logs primarily for visual effect. Even in some functional fireplaces with real flues and chimneys, the draft and firebox geometry is so poor that very little usable heat is produced. Additionally, if the fireplace is not set up to burn outside air, it must draw combustion air directly from the living areas, and this is the very air we are trying to heat up. Drawing air from the rest of the house up the chimney often results in a net heat loss, even if you are furiously burning wood or gas.

New homebuilders have apparently reasoned, why invest tremendous amounts of money in constructing functional fireplaces when these new homes have perfectly adequate, high-efficiency, forced-air natural gas or oil furnace systems?

As you may have already figured out, even a gas furnace needs electrical power in order to run the blower in the air handler, fan controller, and thermostat circuit. Even if you have circulating hot water heat, there are often small pumps that circulate the hot water through the radiators or baseboard heat exchangers. Oil-fired heaters use an electrically powered pump and blower to burn the fuel oil in a combustion chamber. Without a fully functional fireplace and a good quantity of dry wood in storage, a home with any of these heating systems is vulnerable to complete heat loss in the event of lost electrical service.

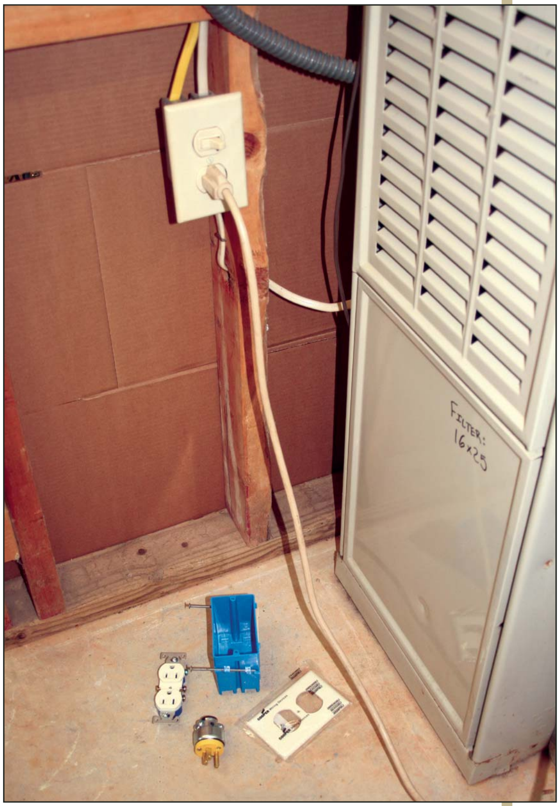
General statistics are difficult to obtain for this phenomenon, but the chances are good that in a given five-year period, anyone living in more northern climates will sustain a power hit during the winter lasting more than just a few hours. After more than one day in subfreezing temperatures, there are additional risks of water pipes bursting, loss of pets, and other disastrous consequences.

The good news is that in a typical, natural gas-fired furnace, the electrical requirements for continued operation are fairly minor. And, when the home is up to temperature, the duty cycle is not continuous. This sort of load is well-suited to inverter use.

What is an Inverter?

An inverter takes a DC power input — like that from a 12-volt battery — and provides an AC power output at 60-cycles, 110V. This is sometimes referred to as "house current." New inverter technology employing MOSFET output drivers and more creative

■ FIGURE 1



primary oscillator stages has enabled near sine wave output at a very low cost and high efficiency. These inverters are safe for use on all types of sensitive electronic equipment and small inductive loads — like a furnace blower fan.

How Much Inverter?

The answer — "as little as you can get by with," is not intended to be a joke. Actually, it means you will get the longest run time for the power supply you have available. In the case of an inverter, this will usually be a lead-acid or gell-cell type battery. As inverters increase in rated capacity, they tend to need higher amounts of power at standby. By sizing your inverter optimally, you can get the longest life out of your battery in a heating emergency.

Begin by establishing the electrical power requirements for your furnace fan. You may get lucky and find this listed on the manufacturer's nameplate or in the furnace instruction manual. You can also establish it empirically by running your furnace and measuring with an amprobe or amp/watt meter. This will establish the startup and steady state power requirements for the furnace.

Another way to get a ballpark guess is to look at the fan motor in your air handler. Most fractional horsepower motors will have the operating voltage and current on a label or nameplate. It also may list a horsepower figure. Please note that if the air handler motor is not a 120 VAC motor, this project will not work for you. Make sure your air handler is not also powering an A/C compressor or an electrically powered heating element. The common AC inverter we are employing cannot run 220/240 VAC equipment. Attempting to do so can be dangerous and could damage both the furnace and inverter.

You can estimate the power required by your motor from its horsepower rating as follows:

Horsepower	Approx. Wattage
1.0	746
3/4	560
1/2	373
1/3	249
1/4	187

If your fan motor lists its power consumption in volts and amps, a general power consumption figure can be calculated by multiplying the two numbers together, Volts x Amps = Watts (VA). This number will be sufficient to size your inverter.

Once you have established the basic power requirement of your fan motor, you will have to double it. The reason for this is that most air-handler fan motors are capacitor-start motors requiring a large amount of inrush current in order to get started. Your inverter must be capable of supplying this current for the project to work. The good news is that many well-constructed modern inverters are capable of withstanding overloads, some up to 100% of rated output capacity, for a very short time. A few seconds or so is long enough to get the fan motor started, so if your inverter is a good quality one, you may discover it will work fine even if it is fairly close to the rated power rating of your fan motor.

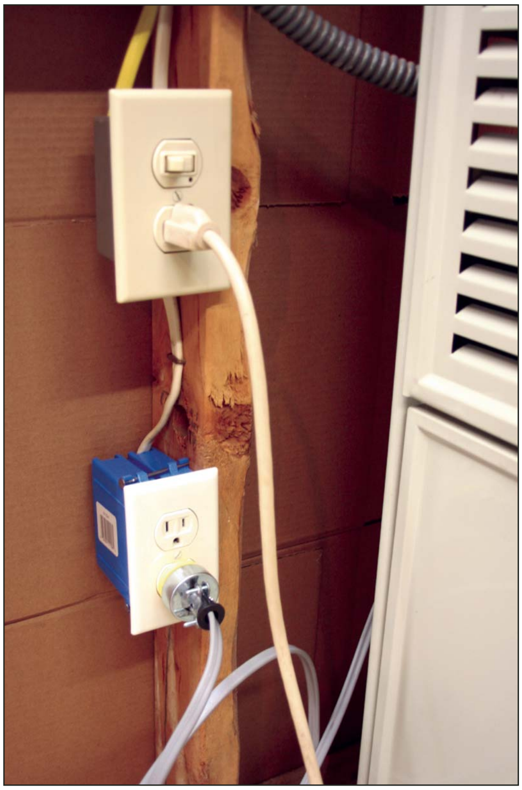
For lower quality inverters, you may discover that one capable of twice or more the fan motor rated power consumption will be needed to start it. Some split-phase and split-capacitor multi-speed air handler motors require more power to get them moving initially and you should take this into consideration. The safest and most reliable arrangement is to size your inverter so it is as large as your air-handler peak power requirement at startup, plus a little bit.

Getting Started

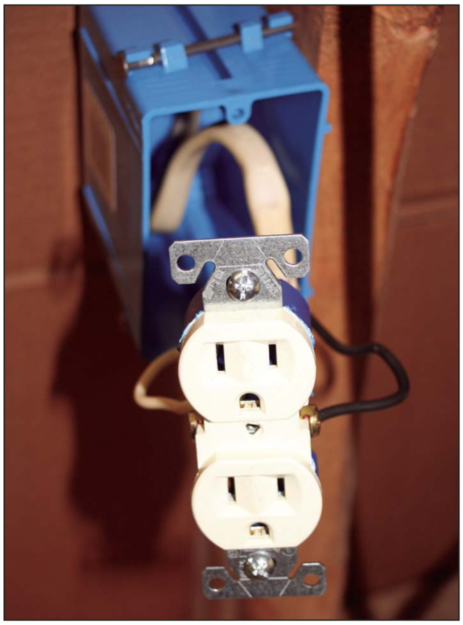
Most furnaces require dedicated electrical branch circuits by code. You should be able to identify which circuit breaker controls the furnace by shutting it off while the furnace is running. Additionally, there should be a local service disconnect located somewhere near the actual furnace. In our case, this is a lighted wall switch outlet (Figure 1). The auxiliary outlet also supplies power to the air-conditioner condensate pump. The main modification we will make is to add an additional "service disconnect" between the existing one and the air handler, in the form of a standard plug and outlet. This will allow us to unplug our air handler from main power and transfer it to our inverter in the event of a power outage.

With the power off at the main breaker box, carefully remove the air-handler power line from the service

■ FIGURE 2



■ FIGURE 3a

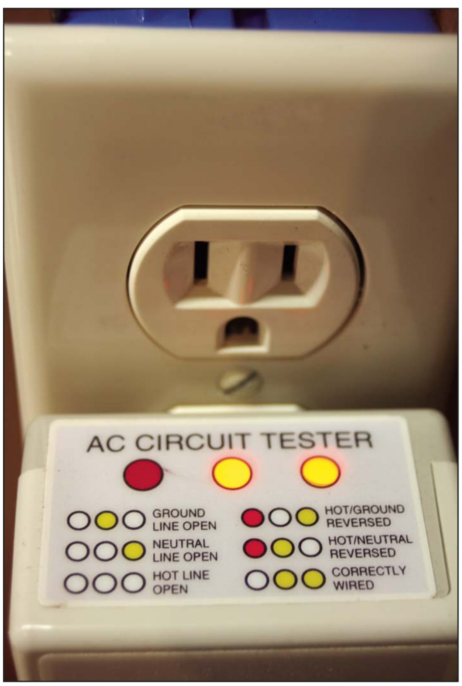


■ FIGURE 3b

disconnect and wire it to a standard 15-amp grounded plug (Figure 2).

Wire a small stub of grounded 14-2 from the original service disconnect to a standard 15-amp grounded outlet box. Screw or nail the outlet box to a stud (Figure 3a). Use a cable strain relief or make sure the box has one — the plastic boxes usually do. Finally, wire in a 15-amp outlet.

■ FIGURE 4



Make sure you observe proper wiring conventions (Figure3b):

Black — Hot (Narrow Spade)
White — Neutral (Wide spade)
Green — Ground

Before plugging your air handler back in, turn on the breaker and recheck to make sure your wiring and polarities are correct. A plug-in neon light polarity tester will be handy in performing this test (Figure 4).

Trying Out the Inverter

You could wait for the next ice storm, blizzard, or power blackout, but you should run a few tests to make sure this is really going to work.

Shut the power off to your furnace at the main breaker box. Generally, a furnace also provides power to its associated thermostat through the control wires, so when the power is off, the thermostat will also lose power. Programmable setback thermostats have backup batteries and may or may not operate without AC power, so you must verify proper thermostat operation when running on an inverter.

Our air handler fan is a 1/3 HP unit. We measured 6.5A for two seconds at startup, then 2.3A when running with the amprobe. This translates to approximately 715W to start and 250W to run. Inexpensive inverters are generally available in 250-watt or so incremental capacities, so we tested several different inverter units.

The first inverter we tried was an unmodified 520W UPS with internal batteries. It was unable to start the furnace fan. We knew this, based on our calculations above. Next, we tried an inexpensive 750W modified square-wave output UPS. It was able to start the furnace fan. Next, we ran on a 1,200W UPS modified to run on an external lead-acid battery. (See my December 1997 *Nuts & Volts* article on how to do this). Finally, we plugged in a 2,400W trace inverter in our van and ran the furnace with no problems on that. The trace has the added advantage of load sensing so the standby power draw is negligible.

PARTS LIST

QTY.	DESCRIPTION
❑ 1	"Carlon" or other single outlet junction box
❑ 1	Grounded outlet
❑ 1	Outlet cover
❑ 1	15 amp grounded plug
❑ 1	3" (or more) of 14-2 (with ground) wire
❑ 1	Adequately sized UPS or inverter with external or internal battery (*see text*)

Other materials may include wire stripper, wire nuts, wiring polarity tester.

How Long Can You Stay Warm?

The answer to this question depends on several interrelated factors: the efficiency of the inverter; standby power draw; the outside/inside temperature differential you are trying to hold; and the condition and capacity of the battery powering your inverter setup.

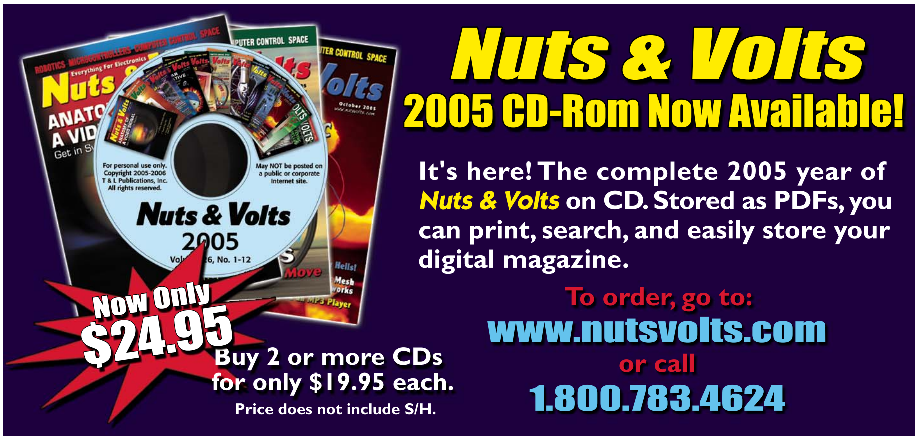
You can estimate this from some observations. If your inverter is running off a deep-cycle "trolling motor" battery in good condition and state of charge, you have about 200 amp-hours of capacity available. Omitting start power draws completely, we know our 250W air handler motor will draw about 20A from the battery when it is running. This equates to 10 hours of continuous run time. Fortunately, we don't have to run the furnace continuously. Holding the house temperature at 70°F when the outside temperature is near 30°F causes the furnace to cycle on for about five minutes and then off for 15 minutes, or a total of 20 minutes an hour (about 33% duty cycle). Our cheapest inverter drew half an amp from the battery even in standby mode, or a continuous six watts of power.

One reasonable estimate would be that we could run our furnace on the inverter under these conditions for about 30 hours. If we were running on the van-based inverter, we could start the van occasionally to recharge the battery and probably extend the run time to a week or more. (*Never run your car in a closed garage under any circumstances!*)

Conclusion

Running your furnace on an AC inverter is a practical alternative to abandoning your home when the power goes out in a storm, if the situation resolves itself in less than a week or so. Remember, this is not a substitute for prudent action like evacuation in the face of a life-threatening emergency or natural disaster.

Remember to be safe, and have fun (and power!) whatever you do! **NV**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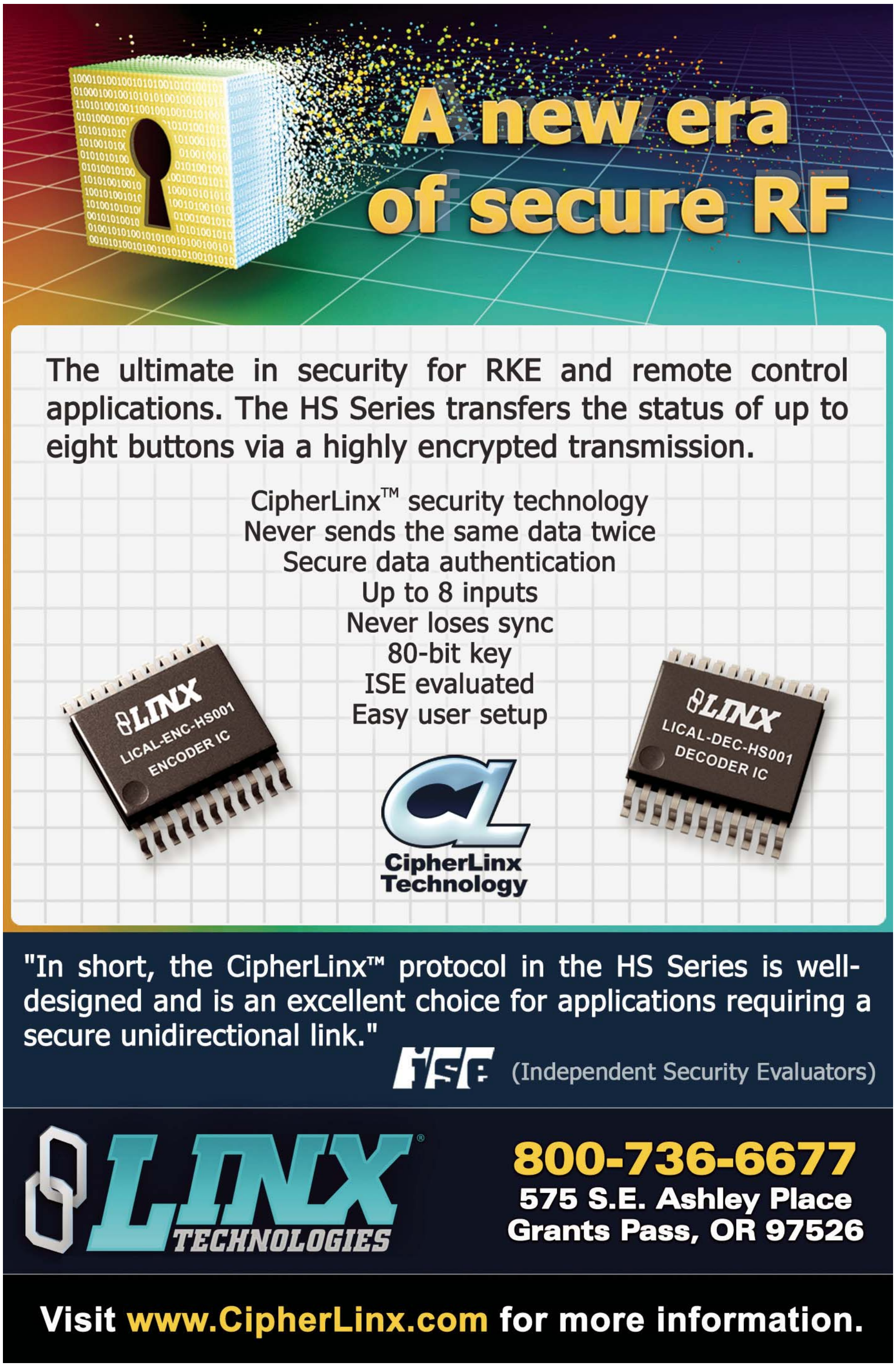
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Nicole Kidman and Mel Gibson live down under. Does that mean we live up over? We learn at an early age which way is down.

Down is where your feet are when you walk and down is the direction you fall.

Gravity dictates the downward direction. If you found yourself aboard the International Space Station, you would be in zero gravity and couldn't tell up from down.

■ FIGURE 1. Basic East-West Compass.

BUILD AN EAST-WEST COMPASS

So you know your way home and you think you know which direction is North. Well, where is the real North? The North pole of a magnetic compass points North, but remember that opposite poles of a magnet attract. In fact, the north geographical pole is actually the magnetic South pole. That places the magnetic South pole of the Earth in the Northern hemisphere near to some Canadian islands. The magnetic North pole is actually found in the Southern hemisphere of the Antarctic. To add further confusion to this situation, geologists refer to the magnetic South pole (located in the Northern hemisphere) as the North magnetic pole.

The magnetic field of the Earth is tilted 12° with respect to the geographic axis. The magnetic field near San Francisco has a Northward component, an Eastward component, and a large downward component. So that a normal magnetic compass will point 18° West of true North. The angle between the horizontal magnetic component and the geographical North is called the angle of declination. If the compass is held so the needle is free to revolve about a horizontal axis, it will experience the downward component at 62. This angle is referred to as the "dip of the field."

To confuse the situation even more, the above description is only true outside of France. The French have chosen to define the magnetic poles opposite to our definition. The North pole of an English or German bar magnet will attract the North pole of a French bar magnet. In this case, likes attract and opposites repel.

So where did all this begin? There are many legends about magnets. The most commonly accepted story is that nearly 4,000 years ago, an elderly shepherd named Magnes noticed that the nails in his shoes were attracted to a black rock. The rock was later named magnetite, either after Magnes or his Grecian village of Magnesia. Hundreds of years ago, Chinese sailors realized that needle-shaped magnetite always point in a North-South direction and created a rudimentary compass. This led to the stone being called Lodestone or "Leading Stone" and for centuries travelers have relied upon compasses for navigation.

Before the invention of the compass around the 12th century, the only navigational reference was the Sun. In the middle ages, a ship would sail North or South in sight of land to the proper latitude and then sail beyond the sight of land on an East or West course to their destination. Early navigators could determine their latitude by measuring the elevation of the Sun during the day and at night they could determine their latitude from the elevation of the North Star. This led to the design of the Sun compass that relies upon the shadow of the Sun upon a disc. An early Sun compass was excavated from a Viking settlement in Greenland that dates back to around 1,000 AD.

The Sun compass was used as late as World War II for navigation in the featureless deserts of North Africa. The Long Range Desert Group (LRDG), whose adventures produced the famous TV series Rat Patrol, was proficient in the use of the Sun compass. Unlike a magnetic compass, the Sun compass is not influenced by electrical fields from engines or affected by ferromagnetic vehicles.

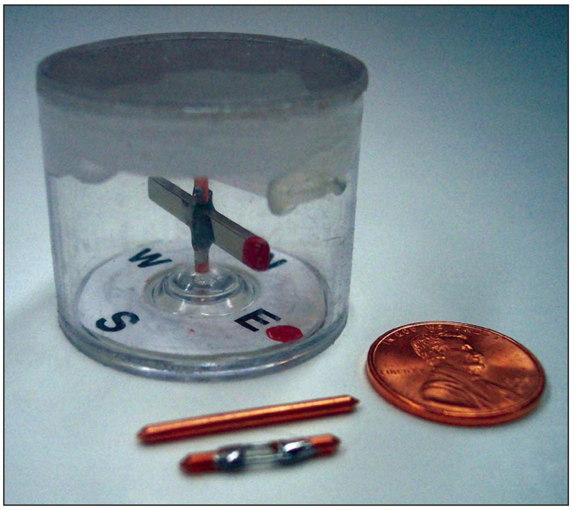
To avoid the confusion of North-South and opposites attracting, let's build an East-West compass. This makes a fascinating introduction to magnets, the compass, navigation, and a great science project for school. An East-West compass has its needle pointing East to where the Sun rises in the morning. How does it work? Well, Alice, you're not in Kansas anymore.

Of course, it works by magic. The needle is made from Solarstone. Solarstone is a very rare Earth material that is sensitive to the Sun's gravitational field and orients the needle so it points in the orbital plane of the Sun. Well okay, that's not quite true. The East-West compass exploits a small but significant difference between magnetic materials. Conventional North-South compass needles are made from an Alnico magnetic material. The East-West compass is made from a rare Earth magnetic material commonly referred to as Neodymium.

Alnico material is an alloy of aluminum, nickel, and cobalt that has been popular since the 1930s. It exhibits a high residual induction, Br, but a low coercive force, Hc. What does this mean? It means the magnetic field can be strong but it is easily demagnetized. To help prevent demagnetization, Alnico magnets are always magnetized along the largest dimension. Thus, it lends itself to a compass needle with the South-North poles at the needle tips.

A Neodymium magnet is composed of neodymium, iron, and boron. It is one of the most recent additions to the family of modern magnetic materials. It exhibits the highest properties of all magnetic materials. It exhibits very high residual induction, Br, as well as very high coercive force, Hc. This material is very difficult to demagnetize and the high-energy product allows magnets to be magnetized along the shortest dimension.

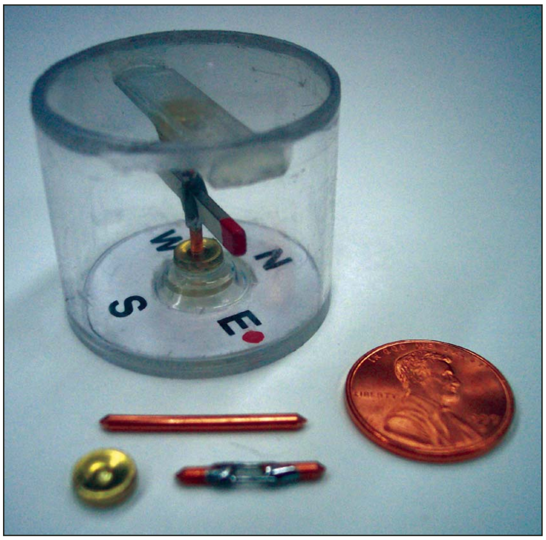
The magnet used in the design of the East-West compass was purchased from K&J Magnetics, Inc. (**www.kjmagnetics.com**). It is described as a Neodymium Block Magnet, part number BX021, with dimensions of 1″ x 1/8″ x 1/16″. It is magnetized through the thinnest dimension, or the 1/16″ dimension. When suitabley suspended, the thinnest dimension will point North-South like a conventional compass, but the longest dimension (1″) of the needle will point East-West. Thus, the magic of the East-West compass is due to the unique properties of a recent magnetic material.



■ FIGURE 2. East-West Compass With Pivot Bearing.

The Neodymium magnet material is made from a sintered powder and is brittle, so do not attempt to cut or drill it. The material is normally susceptible to oxidation, however, the material from K&J Magnetics is nickel-plated to prevent oxidation. It is also temperature sensitive, and will lose its magnetic properties at temperatures above about 150°C.

So how do we suspend the magnet to demonstrate an East-West compass? The simplest suspension is illustrated in Figure 1. Merely support the magnet by tying sewing thread around the middle and support it inside a plastic bottle. You can add a drop of epoxy on the knots to prevent slipping. Mark one end of the magnet with either red paint or a marker pen. When assembled, let the magnet come to rest and then mark the side of the container "East" that corresponds to where the red end of the magnet comes to rest. Continue marking the remaining cardinal directions. Also place a red marker at the "East" direction for a reference. The plastic vial should be about a 1.5″ diameter inside to allow the magnet to swing freely. A 20 Dram vial was used. Suitable containers can be found locally or on the web. McMaster Supply Co. (**www.mcmaster.com**) stocks 4611T25 that is



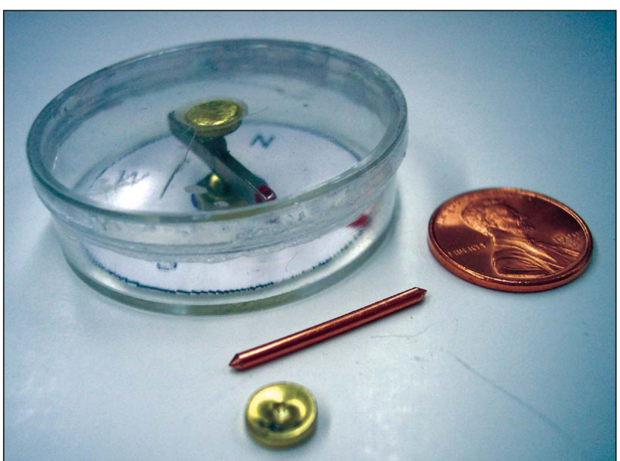
■ FIGURE 3. East-West Compass With Brass Bearing.

20 Drams and 1.58″ diameter by 2.48″ tall.

Other suspension methods that employ a pivot bearing are illustrated in Figures 2, 3, and 4 — in order of increasing difficulty. These are all variations on the same concept. Brass, copper, aluminum, and plastic materials are best to work with around the magnet. Especially, avoid steel pliers and tweezers near the magnet. The pivot pin is made from 14-gauge copper wire that has a diameter close to the magnet thickness. The ends of the wire have been ground to a point angle of about 90°. Any angle less than the point angle of a standard 118° twist drill is satisfactory to reduce the point contact and reduce friction.

Grind the ends of the copper wire with a rigidly fixed Dremel tool or hand drill with a fine grinding stone to obtain a smooth finish. A pin vise is handy to hold the wire while grinding, but not essential. The 14-gauge copper wire was then cut to about a 1/4″ length to form an upper and lower pivot bearing. The ends can be filed flat, if they have been cut with diagonal cutters. Next, two small copper tinned leads are cut from a 1/4-watt resistor to about 5/16″ long. These leads are soldered on each side of one of the 14-gauge pivot pins. To aid in soldering, these leads are taped down to a 1/32″ thick piece of flat brass stock. The brass spacer serves to temporarily hold the small wires and position them near the center of the 14-gauge pivot pin. Both wires are then soldered with a small 25-watt soldering iron.

After soldering the two wires on both sides, the piece is reversed and held flat with a damp paper towel to prevent the solder from melting and the other copper pivot is soldered in place. Figure 2 illustrates the resulting double-ended pivot and saddle formed for the magnet. This construction allows the upper and lower pivot to be bent slightly so that the pivots are axially aligned before mounting the magnet. The magnet is then slid into the saddle and adjusted for center and to be perpendicular to the pivot pins. A small drop of five-minute epoxy will secure the magnet and saddle assembly. When the epoxy has hardened, a dab of red paint can be applied to one end of the magnet to indicate the head that will point East. The paint can be applied to either end at this time.



■ FIGURE 4. East-West Compass in a Culture Dish.

Several plastic vials can be used for the case depending upon what's available locally. Science Kit & Borel Laboratories (**www.sciencekit.com**) stocks WW6687920 plastic vials that are 38 mm (1.5″) diameter by 68 mm (2.68″) tall. The final height can be adjusted by sawing the top off with a fine tooth hacksaw. Figure 2 illustrates the pivot bearing assembly in a plastic vial. The bottom of the vial is labeled with the cardinal directions. A paper label can be printed or transfer lettering can be applied and glued in place. Also indicate the "East" direction with a small dab of red paint.

In this configuration, the bottom center of the vial was drilled with a standard 0.070″ diameter twist drill to about 1/32″ depth. Don't penetrate the bottom of the vial, as the hole serves as the bottom-bearing surface for the copper pivot. Above, a 3/32″ thick piece of plastic was cut to span the upper inside portion of the vial. Cut this piece a bit larger than the opening and file a little at a time to obtain a friction fit. This piece is similarly drilled to provide the upper bearing support. In the final assembly, the magnet assembly is placed in position with the upper plastic bearing pushed down into place. The upper plastic bearing piece is then pulled upward a small amount to allow the magnet to freely rotate but to still constrain the magnet position. With the magnet rotating freely, make sure the red end of the magnet lines up with the red "East" marking on the bottom of the vial.

If the direction is correct, apply a drop of five-minute epoxy to the upper plastic bearing piece to fix its position permanently. If the red dots do not line up, remove the magnet assembly and flip it over to reverse the direction and reassemble. Finally, cut a thin clear plastic cover for the compass and glue it over the top to seal the final assembly. Epoxy or plastic model cement can be used as the adhesive.

Figure 3 illustrates another variation of the East-West compass. Instead of drilling the plastic for the pivot support, a metal pivot support was glued to the vial bottom and the upper plastic bearing piece with five-minute epoxy. The metal pivot support was fabricated by punching out a 1/4″ diameter 1/16″ thick brass disc. The disc was then drilled with a standard 0.070″ diameter twist drill. The same procedure was followed as already explained. The only benefit to the metal bearing surface is to provide longer life.

Another variation is illustrated in Figure 4. This version doesn't use the pivot pin saddle arrangement. The pivot pins are cut down to about 1/8″ long and epoxied directly to the magnet to reduce the overall height. It is much more difficult to epoxy the pivots exactly at the center of the magnet and maintain them along the same axis.

To aid in the assembly, a jig is required to hold the 14-gauge copper pivot pin over the magnet while gluing. When secured, the jig can be flipped over to locate the second copper pivot pin to maintain alignment. This construction allows a plastic culture dish to be used for the container. Brass bearing surfaces were used for both the bottom and top support. The culture dish top also makes assembly very difficult, as there is no way to position the magnet assembly while closing the lid. This reminds me of the problem of assembling a ship in a bottle. It would help to use an upper plastic bearing piece as was done in Figures 2 and 3 to allow the assembly with some access so that final adjustments can be performed before totally sealing the compass.

I really hope this educational project will point you in the right direction. **NV**

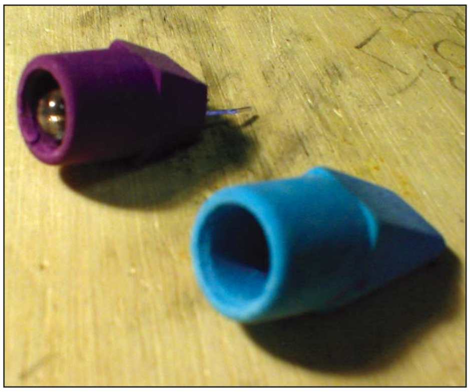
Magnet Websites

- www.dansdata.com/magnets.htm
- http://edhiker.home.comcast.net/North_Pole_Positive_or_Negative.html
- www.magnetsales.com/Design/DesignG_frames/frame_dgbod2.htm
- http://members.aol.com/jvlambert/Norman/SunCompass.htm
- http://my.execpc.com/~rhoadley/magvisual.htm
- www.sciencetech.technomuses.ca/ENGLISH/schoolzone/Info_Magnets.cfm
- http://suncompass.fandom.tv/odds_and_ends.htm

BY JOHN F. MASTROMORO

A short time ago, I was working on a small digital project that required the use of circuit-status indication lights outside of the building that the device was installed in.

■ FIGURE 1



LED WEATHER-PROOF RUBBER ENCLOSURE

LEDs, of course, were the appropriate choice for these indicators and, because of obvious weather conditions, etc., I had to use some sort of "weather-proof" enclosure for the LEDs. On my workbench was a package of those very common pencil-topper erasers that are simply inserted over the end of a pencil. They can be purchased at almost any store that vends this type of product. I purchased a pack of 40 such erasers for less than a dollar at a local WalMart store.

As can be seen in Figure 1, the blue eraser shown is the type that you would use for this project before cutting it down. The purple eraser is shown as it would be after it is cut with an LED inserted into it.

On the pointed end of the eraser, snip off approximately 3/8ths of an inch so that the "pointed end" is now even and flat. It is now just a simple matter of pressing the LED leads through the open end and continuing on through the bottom of the eraser. You should have a fair amount of lead length protruding through the eraser bottom to work with, even for "wire-wrapping" connections. Checking for proper LED voltage polarities is all that is now required.

Warm up your glue gun and have it ready for use. Then — using a common plastic soda-sipping straw — push either open end of the straw around the LED just far enough to cover the tip. Holding the straw in place over the tip of the LED, shoot some glue around the inside of the eraser to seal it, making it weather-proof. Within 20 or so seconds, the glue should be set. Remove the straw and you have a weather-proof enclosure. If you're fairly accurate with your glue gun, then you don't have to use the straw for a petition around the LED.

Once the LED enclosure is completed, then you can see how the eraser has a ridge around it. Take advantage of this and use it as a perfect alignment stopper when placing the enclosure through the proper size hole of another enclosure for display, etc. The rubber quality of the eraser makes it ideal for this purpose, too! **NV**

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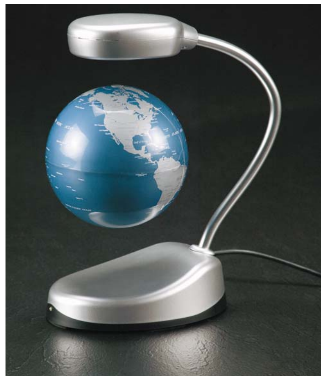

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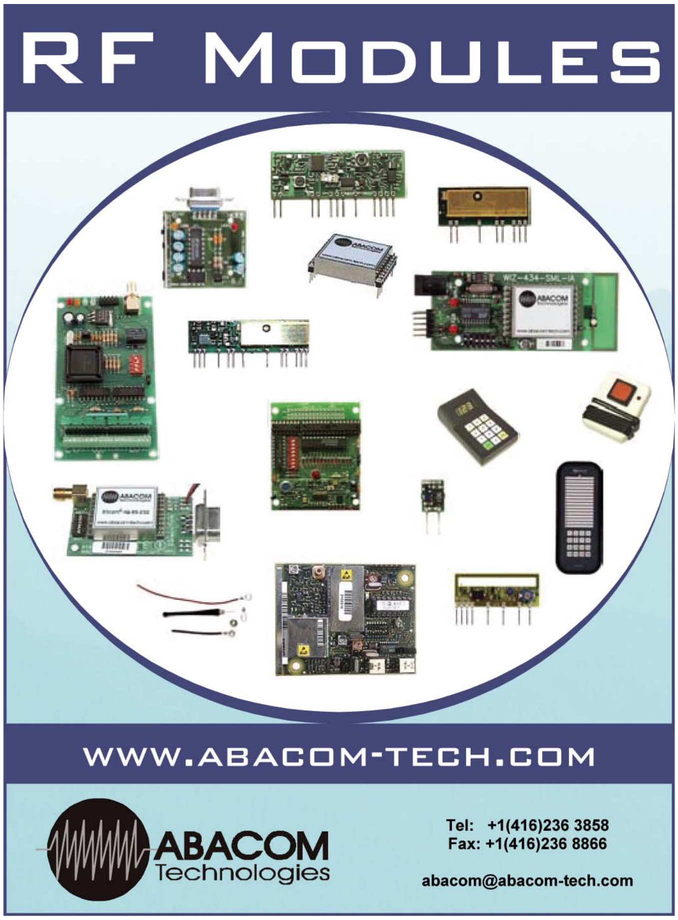
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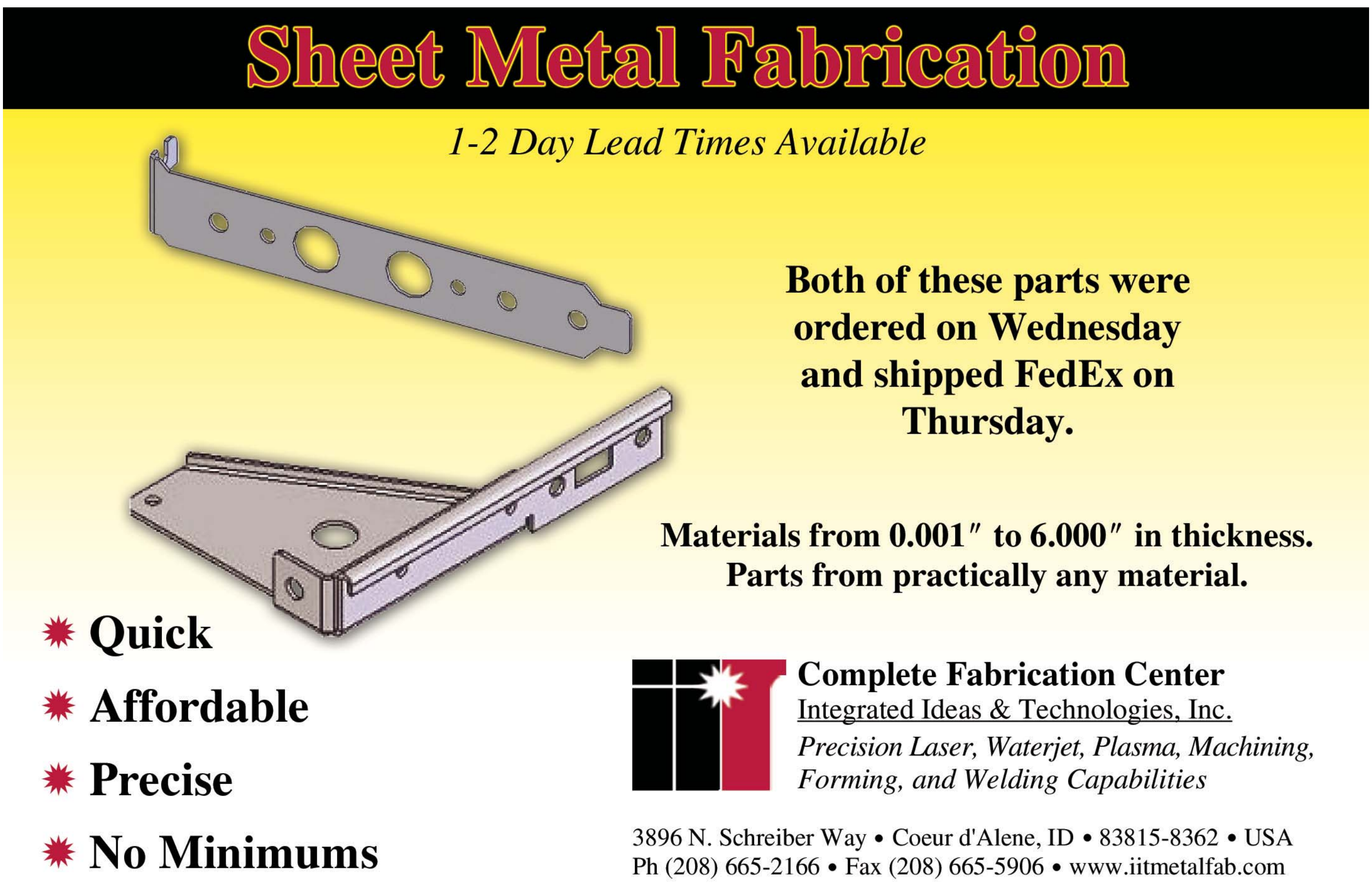
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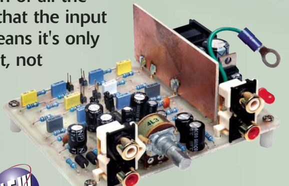
This kit is used to amplify the 3-4mV signals from a phono cartridge to line level, so you can use your turntable with the CD or tuner inputs on your Hi-Fi amplifier. The design is suitable for 12" LPs, and also allows for RIAA equalization of all the really old 78s. Please note that the input sensitivity of this design means it's only suitable for moving-magnet, not moving-coil cartridges. Kit includes PCB with overlay and all electronic components.

• Requires 12VAC power



NEW

Battery Zapper MKII

KC-5427 $58.00 + post & packing

This kit attacks a common cause of failure in wet lead acid cell batteries: sulfation. The circuit produces short bursts of high level energy to reverse the damaging sulfation effect. This new improved unit features a battery health checker with LED indicator, new circuit protection against badly sulfated batteries, test points for a DMM and connection for a battery charger. Kit includes case with screen printed lid, PCB with overlay, all electronic components and clear English instructions. Suitable for 6, 12 and 24V batteries

• Powered by the battery itself

Improved Model!

Galactic Voice Kit

KC-5431 $26.25 + post & packing

Be the envy of everyone at the next Interplanetary Conference for Evil Beings with this galactic voice simulator kit. Effect and depth controls allow you to vary the effect to simulate everything from the metallically-challenged C-3PO, to the hysterical ranting of Daleks hell-bent on exterminating anything not nailed down. The kit includes PCB with overlay, enclosure, speaker and all components. For those who really need to get out of the house a lot more. Take me to your leader.

• Requires 9V battery

Theremin Synthesizer MKII

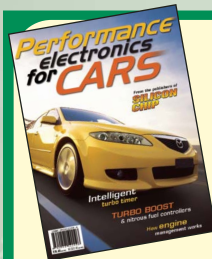
KC-5426 $87.00 + post & packing

By moving your hand between the metal antennae, create unusual sound effects! The Theremin MkII improves on its predecessor by allowing adjustments to the tonal quality by providing a better waveform. With a multitude of controls, this instrument's musical potential is only limited by the skill and imagination of its player. Kit includes stand, PCB with overlay, machined case with silkscreen printed lid, loudspeaker, pitch antennae, all specified electronic components and clear English instructions.

As used in the Beach Boys classic hit 'Good Vibrations'

Improved Model!

Requires 9-12VDC wall adapter (Jameco #252751 $12.05)



High Performance Electronic Projects for Cars Book

We stock an extensive range of quality automotive kits

BS-5080 $14.95 + post & packing

Australia's leading electronics magazine Silicon Chip, has developed a range of projects for performance cars. There are 16 projects in total, ranging from devices for remapping fuel curves, to nitrous controllers. The book includes all instructions, components lists, color pictures, and circuit layouts. There are also chapters on engine management, advanced systems and DIY modifications. Over 150 pages! All the projects are available in kit form, exclusively to Jaycar. Check out our website for all the details.

IR Romote Control Extender MKII

KC-5432 $14.50 + post & packing

Operate your DVD player or digital decoder using its remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the device. This improved model features fast data transfer, capable of transmitting Foxtel digital remote control signals using the Pace 400 series decoder. Kit supplied with case, screen printed front panel, PCB with overlay and all electronic components.

Improved Model!

Requires 9VDC wall adaptor (Jameco #252751 $12.05)

Hand Controller for Digital Adjusters

KC-5386 $37.95 + post & packing

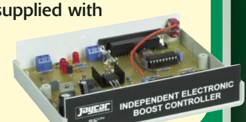
This hand controller is used for mapping/programming the independant electronic boost controller Kit (shown right). It features a two line LCD, and easy to use push buttons. It can be used to program the adjusters then removed, or left permanently connected to display the adjuster's operation. It is designed as an interface and display, and is not required for general adjuster functions after they have been programmed. Kit supplied with silkscreened and machined case, PCB, LCD, and all electronic components.

Independent Electronic Boost Controller

KC-5387 $50.95 + post & packing

It can be used in cars fitted with factory electronic boost control using the factory control solenoid, or cars without electronic boost control using a solenoid from a wrecker etc. This is ideal for switching between say, a race/street mode, or a performance/ wet weather mode. Boost curve selection is via a dashboard switch, and is all programmed using the handheld digital controller KC-5386 (shown left). Kit supplied with PCB, machined case, and all electronic components.

• Suitable for EFI and engine management systems only



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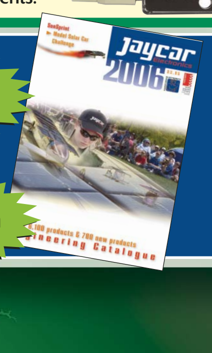


Jaycar Electronics

PROTECTION AGAINST SPAM

Anonymizer® Inc., a leader in identity protection technology and privacy solutions, has unveiled the newest addition to its full line of products, Anonymizer Nyms™. Users can now instantly create anonymous, disposable email addresses to protect their personal accounts against spam and — even more importantly — the digital threats that typically arrive with spam, such as viruses, worms, spyware, adware, phishing scams, and more.

In today's world of easily accessible electronic data, people are learning to become more cautious about the personal information they provide to the external world. However, it's nearly impossible to shop or game online, attend a tradeshow or Web event, or even join a softball league without giving someone (or some website) your email address. Yet, every time you provide your personal email address, you lose control over how it is used and you will eventually become easy prey to spammers.

Anonymizer Nyms protects customers' real email addresses with anonymous, disposable ones. By creating a Nyms email address every time an email address is required, users are able to control incoming mail. Additionally, they can even identify exactly where spam is being initiated. When a user determines that an email address has been shared with spammers, they can simply deactivate that Nyms account and stop the spam from flooding their in-box.

"Anonymizer Nyms is more effective than spam filters because this new solution stops the unsolicited email from coming in," said Lance Cottrell, president and chief scientist of Anonymizer. "Plus, it keeps your personal email address, and ultimately your privacy, protected."

Customers can maintain their privacy by using anonymous Nyms email addresses with untrusted sources. For example, if they want to comment on an article, check on the status of an order, or request more information from a vendor's sales department, they can use an anonymous Nyms email address to keep their personal one protected.

Anonymizer Nyms redirects all incoming email to a user's primary address. This makes it easier to manage than creating second, third, or fourth email accounts that keep people checking multiple email boxes for messages daily.

Anonymizer Nyms is available for an annual subscription of $19.99. Customers can also purchase the new Anonymizer Safe Surfing Suite®, which includes Anonymizer Nyms coupled with Anonymous Surfing®, Anonymizer Digital Shredder®, and Anonymizer Anti-Spyware®. An annual subscription to the Anonymizer Safe Surfing Suite is available for

$49.99. Both Anonymizer Nyms and the Anonymizer Safe Surfing Suite are available for download via the Web at **www.anonymizer.com**.

Anonymizer Nyms is also available in the Anonymous Surfing Platinum®, a product suite available exclusively in retail stores such as Office Depot, OfficeMax, CompUSA, and Fry's.

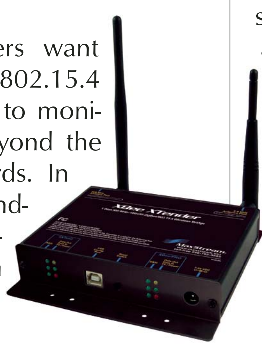
RAPID CELL PHONE BATTERY TESTING

Cadex Electronics has developed a revolutionary rapid-test method that checks the performance of cell phone and PDA batteries in 30 seconds. QuickSort™ is based on electrochemical dynamic response rather than resistance measurement. Built into the Cadex C7000 C-Series battery analyzers, the patented Quick-Sort achieves a sorting accuracy of 90% and services batteries with a state-of-charge of 40-100%. The analyzers also revive over-discharged packs and provide full battery analysis.

ZIGBEE RANGE IS EXTENDED UP TO 40 MILES

MaxStream (**www.maxstream.net**) now offers the XBee XTender™ wireless bridge that extends the range of ZigBee™ and 802.15.4 networks up to 40 miles. Because the ZigBee and 802.15.4 standards focus on low-cost, low-power wireless monitoring and controlling of electronic devices, ZigBee modems typically must be located within 100-300 feet to communicate.

Many customers want to connect ZigBee/802.15.4 networked devices to monitoring locations beyond the range ZigBee affords. In order to meet extended distance requirements, MaxStream has combined the strengths of its XBee™ and XTend™ product lines into a wireless bridge. The multi-band XBee XTender permits shorter range 2.4 GHz XBee networks operating under the ZigBee or 802.15.4 wireless personal area network (WPAN) standards to communicate data up to 40 miles away via the powerful 900 MHz, one watt XTend RF modem.



The low-power consumption of the XBee network makes it ideal for a wide range of battery-powered applications, while the high-power XTend can transmit through obstacles that would otherwise impede devices communicating via ZigBee/802.15.4. The range of the XTend coupled with the versatility and cost-savings of the XBee network give OEMs and systems integrators greater flexibility when designing wireless networks.

TISSUE AND ORGAN REGENERATION

Scientists in Texas have agreed to design the next generation of cost-effective tissue and organ regeneration, wound care, and scar healing ingredients. The scientists are based at the Texas A&M Bioseparations Lab of Biological and Agricultural Engineering Department, and the Institute for Plant Genomics and Biotechnology. Martin B. Dickman, Ph.D., Director of the Institute for Plant Genomics and Biotechnology at Texas A&M, and Zivko L. Nikolov, Ph.D., a Dow Professor from the Texas A&M Biological and Agricultural Engineering Department, will coordinate on the project with Burt Ensley, PhD., Microbiologist, CEO of DermaPlus, Inc. Drs. Dickman and Nikolov have signed a Letter of Intent to collaborate as part of the University's War Wound Healing and Tissue Regeneration Project. They will mount a research project with DermaPlus directed toward improving the quality and availability of human Tropoelastin (Elastotropin™) when used to heal soldiers' battlefield injuries.

Continued on Page 96

Is LITHIUM-ION Safe?

Major Battery Recall Raises Concern

by Isidor Buchmann

When Sony introduced the first lithium-ion battery in 1991, they knew of the potential safety risks. A recall of the previously released rechargeable metallic lithium battery was a bleak reminder of the discipline one must exercise when dealing with this high energy-dense battery system.

Pioneering work for the lithium battery began in 1912 by G. N. Lewis. It was not until the early 1970s when the first non-rechargeable lithium batteries became commercially available. Attempts to develop rechargeable lithium batteries followed in the eighties. These early models were based on metallic lithium and offered very high energy density.

However, inherent instabilities of lithium metal, especially during charging, put a damper on the development. The cell had the potential of a thermal run-away. The temperature would quickly rise to the melting point of the metallic lithium and cause a violent reaction. A large quantity of rechargeable lithium batteries sent to Japan had to be recalled in 1991 after the pack in a cellular phone released hot gases and inflicted burns to a man's face.

Because of the inherent instability of lithium metal, research shifted to a non-metallic lithium battery using lithium ions. Although slightly lower in energy density, the lithium-ion system is safe, providing certain precautions are met when charging and discharging. Today, lithium-ion is one of the most successful and safe battery chemistries available. Two billion cells are produced every year.

Lithium-ion holds twice the energy of a nickel-based battery and four-times that of lead acid. Lithium-ion is a low maintenance system, an advantage that most other chemistries cannot claim. There is no memory and the battery does not require scheduled cycling to prolong its life. Nor does lithium-ion have the sulfation problem of lead acid that occurs when the battery is stored without periodic topping charge. Lithium-ion has a low self-discharge and is environmentally friendly. Disposal causes minimal harm.

With the high usage of lithium-ion in cell phones, digital cameras, and laptops, there are bound to be issues. A one-in-200,000 failure rate triggered a recall of almost six million lithium-ion packs used in laptops manufactured by Dell and Apple. Heat-related battery failures are taken very seriously and manufacturers chose a conservative approach. The decision to replace the batteries puts the consumer at ease and lawyers at bay. Let's now take a look at what's behind the recall.

Sony Energy Devices (Sony), the maker of the lithium-ion cells in question, says that on rare occasions microscopic metal particles may come into contact with other parts of the battery cell, leading to a short circuit within the cell. Although battery manufacturers strive to minimize the presence of metallic particles, complex assembly techniques make the elimination of all metallic dust nearly impossible. Energy dense cells with ultra-thin separators are more susceptible to impurities than older designs with lower Ah ratings.

A mild short will only cause an elevated self-discharge. Little heat is generated because the discharging energy is very low. If, however, enough microscopic metal particles converge on one spot, a major electrical short can develop and a sizable

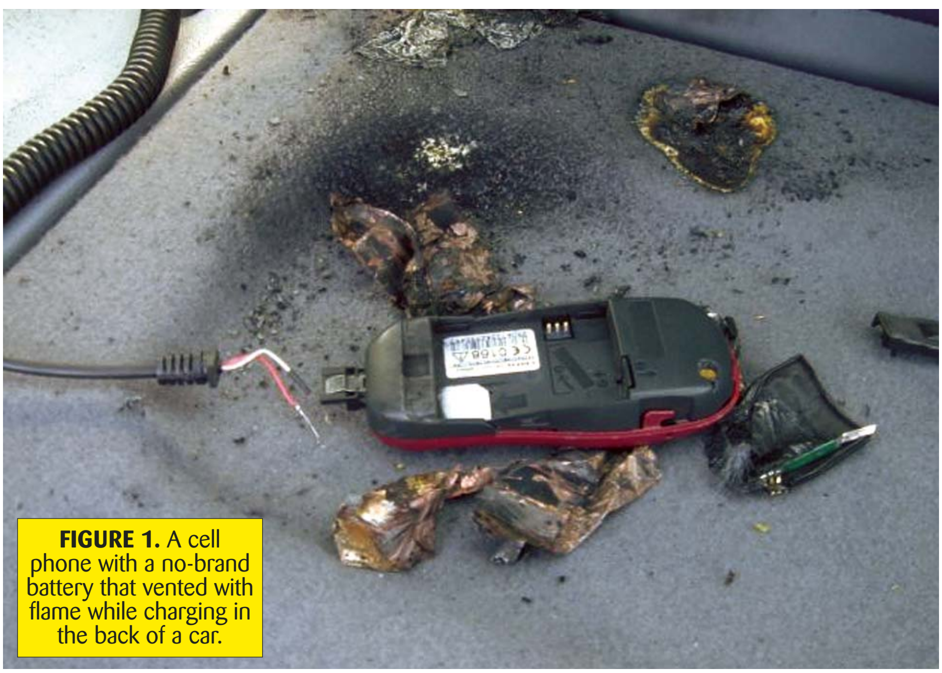


FIGURE 1. A cell phone with a no-brand battery that vented with flame while charging in the back of a car.

current will flow between the positive and negative plates. This causes the temperature to rise, leading to a thermal runaway, also referred to as "venting with flame."

Lithium-ion cells with cobalt cathodes (same as the recalled laptop batteries) should never rise above 130°C (265°F). At 150°C (302°F), the cell becomes thermally unstable, a condition that can lead to a thermal runaway in which flaming gases are vented.

During a thermal runaway, the high heat of the failing cell can propagate to the next cell, causing it to become thermally unstable, as well. In some cases, a chain reaction occurs in which each cell disintegrates at its own timetable. A pack can get destroyed within a few short seconds or linger on for several hours as each cell is consumed one-by-one. To increase safety, packs are fitted with dividers to protect the failing cell from spreading to neighboring cells.

Safety Level of Lithium-ion Systems

There are two basic types of lithium-ion chemistries: cobalt and manganese (spinel). To achieve maximum runtime, cell phones, digital cameras, and laptops use cobalt-based lithium-ion. Manganese is the newer of the two chemistries and offers superior thermal stability. It can sustain temperatures of up to 250°C (482°F) before becoming unstable. In addition, manganese has a very low internal resistance and can deliver high current on demand. Increasingly, these batteries are used for power tools and medical devices. Hybrid and electric vehicles will be next.

The drawback of spinel is lower energy density. Typically, a cell made of a pure manganese cathode provides only about half the capacity of cobalt. Cell phone and laptop users would not be happy if their batteries quit halfway through the expected runtime. Rather than less, the consumer wants more stored energy to support new features that chew up extra battery power.

To find a workable compromise between high energy density, operational safety, and good current delivery, manufacturers of lithium-ion batteries use different cathode metals. Typical mixes are cobalt, nickel, manganese, and iron phosphate. Lithium-ion systems are not yet mature and have the potential of increasing the energy density further. Looking back in history, lithium-ion has achieved a notable energy improvement of 8-10% per annum.

Packing more energy into a cell increases safety concerns and appropriate measures will need to be taken to achieve the mandated safety standard set forth by UL 1642. Whereas a nail penetration test could be tolerated on the older 1.35 Ah 18650 cell, a high-density 2.4 Ah would become a bomb when performing the same test. UL 1642 does not require nail penetration.

"The temperature would quickly rise to the melting point of the metallic lithium and cause a violent reaction."

Battery Safety Comes First

Let me assure the reader that lithium-ion batteries are safe and heat-related failures are rare. The battery manufacturers achieve this high reliability by adding three layers of protection. They are: [1] limiting the amount of active material to achieve a workable equilibrium of energy density and safety; [2] inclusion of various safety mechanisms within the cell; and [3] the addition of an electronic protection circuit in the battery pack.

These protection devices work in the following ways: The PTC device built into the cell acts as a protection to inhibit high current surges; the circuit interrupt device (CID) opens the electrical path if an excessively high charge voltage raises the internal cell pressure to 10 Bar (150 psi); and the safety vent allows a controlled release of gas in the event of a rapid increase in cell pressure.

In addition to the mechanical safeguards, the electronic protection circuit external to the cells opens a solid-state switch if the charge voltage of any cell reaches 4.30V. A fuse cuts the current flow if the skin temperature of the cell approaches 90°C (194°F). To prevent the battery from over-discharging, the control circuit cuts off the current path at about 2.50V/cell. In some applications, the higher inherent safety of the spinel system permits the exclusion of the electric circuit. In such a case, the battery relies wholly on the protection devices that are built into the cell.

We need to keep in mind that these safety precautions are only effective if the mode of operation comes from the outside, such as with an electrical short or a faulty charger. Under normal circumstances, a lithium-ion battery will simply power down when a short circuit occurs. If, however, a defect is inherent to the electrochemical cell — such as in contamination caused by microscopic metal particles — this anomaly will go undetected. Nor can the safety circuit stop the disintegration once the cell is in thermal runaway mode. Nothing can stop it once triggered.

A major concern arises if static electricity or a faulty charger has destroyed the battery's protection circuit. Such damage can permanently fuse the solid-state switches in an ON position without the user knowing. A battery with a faulty protection circuit may function normally but does not provide protection against abuse.

Another safety issue is cold temperature charging. Consumer grade lithium-ion batteries cannot be charged below 0°C (32°F). Although the packs appear to be charging normally, plating of metallic lithium occurs on the anode while on a sub-freezing charge. The plating is permanent and cannot be removed. If done repeatedly, such damage can compromise the safety of the pack. The battery will become more vulnerable to failure if subjected to impact, crush, or high rate charging.

Asia produces many non-brand replacement batteries that are popular with cell phone users because of low price. Many of these batteries don't provide the same high safety standard as the main brand equivalent. A wise shopper spends a little more and replaces the battery with an approved model. Figure 1 shows a cell phone that was destroyed while charging in a car. The owner believes that a no-name pack caused the destruction.

To prevent the infiltration of unsafe packs on the market, most manufacturers sell lithium-ion cells only to approved battery pack assemblers. The inclusion of an approved safety circuit is part of the purchasing requirement. This makes it difficult for a hobbyist to purchase single lithium-ion cells off-the-shelf in a store. The hobbyist will have no other choice than to revert to nickel-based batteries. I would caution against using an unidentified lithium-ion battery from an Asian source, if such cells are available.

The safety precaution is especially critical on larger batteries, such as laptop packs. The hazard is so much greater than on a small cell phone battery if something goes wrong. For this reason, many laptop manufacturers secure their batteries with a secret code that only the matching computer can access. This prevents non-brand-name batteries from flooding the market. The drawback is a higher price for the replacement battery. Readers of **www.BatteryUniversity.com** often ask me for a source of cheap laptop batteries. I have to disappoint the shoppers by directing them to the original vendor for a brand name pack.

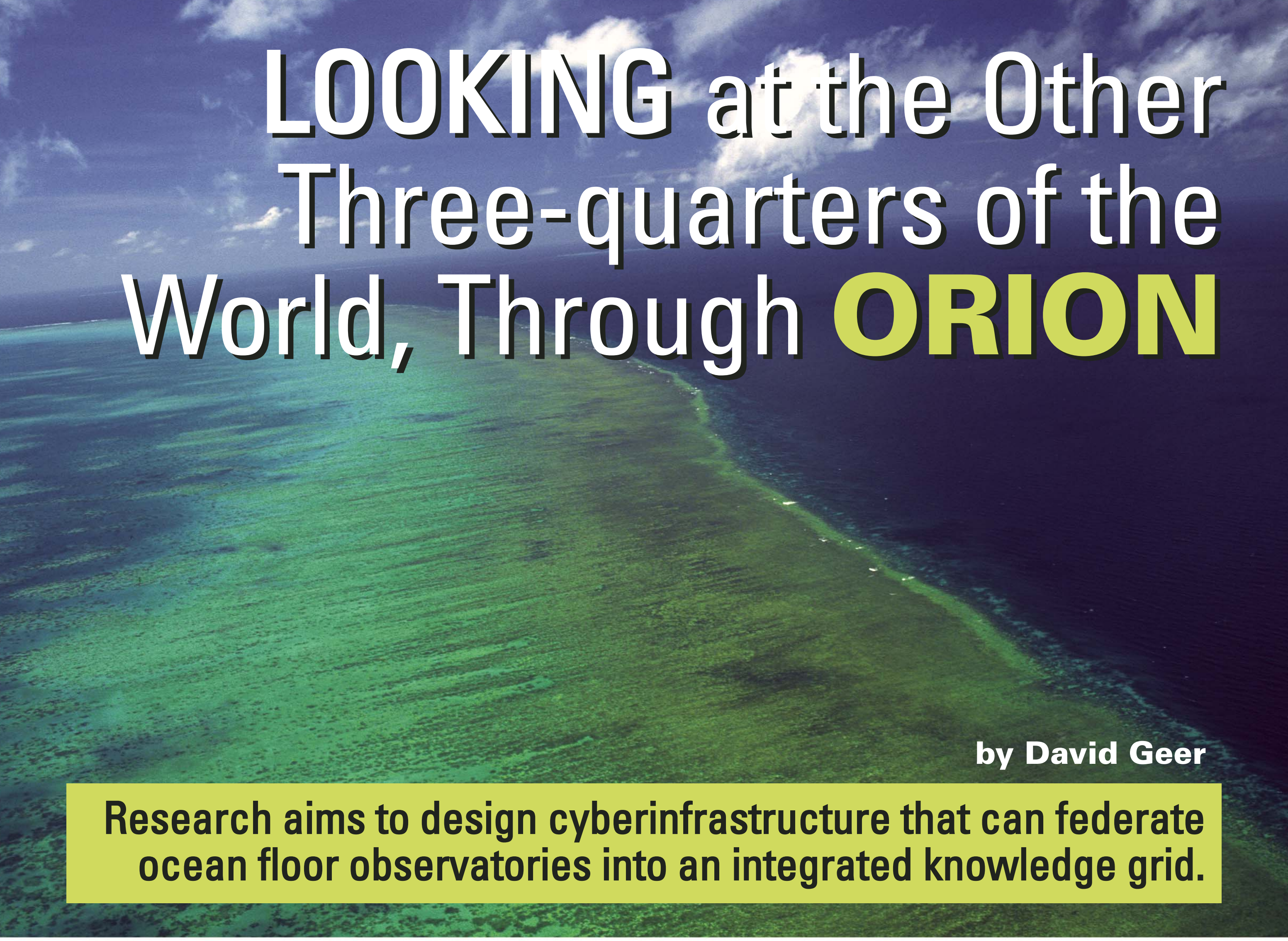
Conclusion

Considering the number of lithium-ion batteries used on the market, this energy storage system has caused little harm in terms of damage and personal injury. In spite of the good record, its safety is a hot topic that gets high media attention, even on a minor mishap. This caution is good for the consumer because we will be assured that this popular energy storage device is safe. After the recall of Dell and Apple laptop batteries, cell manufacturers will not only try packing more energy into the pack but will attempt to make it more bulletproof. **NV**

ABOUT THE AUTHOR

Isidor Buchmann is the founder and CEO of Cadex Electronics, Inc., in Vancouver BC. Mr. Buchmann has a background in radio communications and has studied the behavior of rechargeable batteries in practical, everyday applications for two decades. Award winning author of many articles and books on batteries, Mr. Buchmann has delivered technical papers around the world.

LOOKING at the Other Three-quarters of the World, Through ORION



by David Geer

Research aims to design cyberinfrastructure that can federate ocean floor observatories into an integrated knowledge grid.

The Laboratory for the Ocean Observatory Knowledge Integration Grid (LOOKING) project (**http://lookingtosea.ucsd.edu**) is examining technologies to accomplish the goals of the ORION (the Ocean Research Interactive Observatory Networks) Program's cyberinfrastructure, which will make data from automated ocean floor observatories available to the world.

Some observatories — which connect groups of sensors to a single fiber optic cable or to buoys — exist today. The sensors they employ include a variety of data collection instruments such as seismometers.

LOOKING and ORION are a part of worldwide research efforts to make data from the ocean depths freely and instantly available to land-based research institutions for grid computing.

LOOKING is the predecessor to the ORION program and is one and a half years into its four year funded project. ORION will provide the federation, data modeling, and web services in an SOA (Service Oriented Architecture) for what will be 11 observatories strung from the coasts of Maine to Southern California and further off shore.

The ORION Cyberinfrastructure

The cyberinfrastructure is in the early stages of design. Existing observatories are individually making their data available as files via FTP or HTTP download, according to Matthew Arrot of Calit2 and member of the ORION cyberinfrastructure committee.

ORION will use partners who already have grid infrastructure, web services, and storage, and integrate these elements to work with the collected data.

ORION cyberinfrastructure will support ocean floor sensor networks in monitoring ocean environments. Data from various regions of the oceans will be modeled. Data models will be trained on new data every six hours. Measurements are gathered, defined by the output of the previous measurement and weighted on clusters of information from the measurement, according to Arrot.

The assimilated data is used to realign the model, then the new information is used in the next run of the model for the next measurement (in this way, the model improves its own accuracy every six hours). A new forecast covering what is expected in the ocean environment is made every six hours that covers the next 72 hours. This will be provided to researchers through the Teragrid and

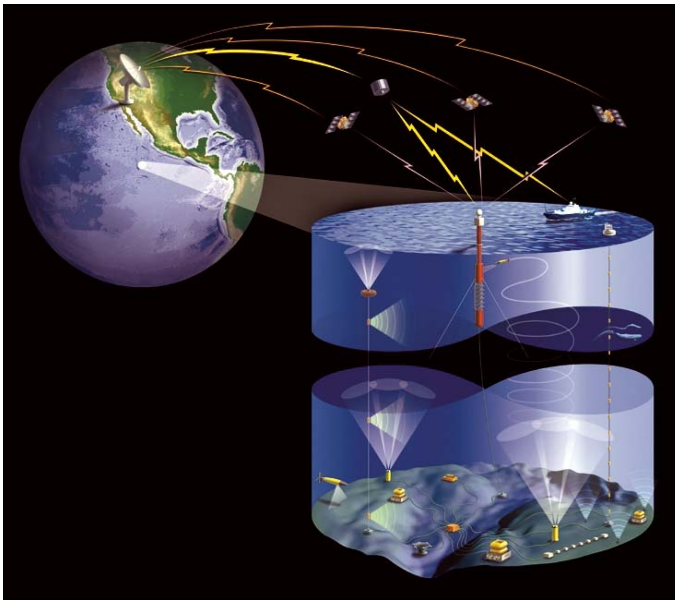


FIGURE 1. This shows buoyed unmanned undersea observatories with sensing instruments attached to fiber optic cable networks which send collected data back through the observatory and on to the rest of the world for study and collaborative research.

by having individual researchers plug their systems into ORION's Web Services via the Internet backbone, according to Arrot.

According to Arrot, ORION program researchers will interact with the instruments through a common instrument interface. This interface is connected to an Enterprise Service Bus (ESB, an integration architecture that enables incremental integration). This ESB architecture rides on top of the TCP/IP (or possibly UDP — yet to be determined) protocol that will be used across the infrastructure for data transport.

The selected data transport technology will also support shore-to-sensor communications for command-and-control operations and calibration, as well as sensor-to-sensor communications, according to Tim McGinnis, senior engineer at the Applied Physics Lab, University of Washington.

The ESB uses a messaging layer (with messaging software designed for large scale distributed application environments to send data in real-time) that sends the signal, i.e., streaming data containing each new interval of measurement data, to the archives in the repositories and to researchers subscribed to the signal. Three independent operators will be selected over the next six to 12 months to supply and take care of the archiving repositories. One operator each will be selected for the coastal, regional, and global observatories.

Underpinning all three operators is a fourth — the cyberinfrastructure independent operator — which will be responsible for the operating infrastructure, says Arrot.

Around the Enterprise Service Bus there is a set of web service templates. The web service templates communicate about certain behavior characteristics coming from the sensors. Examples include the SensorML Schema's measurement characteristics (sensor metadata such as who is operating the sensor, the sensor ID, etc.), Plug-n-Play response characteristics (which have several models for looking at chemistry, radiation, population, and general properties in the ocean), and Manageability Characteristics — WSDM (Web Services Distributed Management) specification events — which look at lifecycles and transitions between different states of the data. These were standardized in LOOKING before ORION, according to Arrot.

There are web services for interacting with the metadata catalog and the repository. There are web services for dealing with storage; this allows operators at the observatory level to pull their own storage facilities into the operating environment in a standard manner. They will be able to reach into the local storage facilities for the individual observatories and aggregate the catalog and guarantee the replication of the data for redundancy, according to Arrot. The web services will also enable the cyberinfrastructure to outsource some storage requirements to supercomputing centers, explains Arrot.

Researchers and entities outside of ORION will be able to connect through portals and web service interfaces to interact with the repository or subscribe to real-time data.

"There will be one or a family of web services associated with workflow. There are services for time and location focused back at the observatories and the instruments to give them a common basis for time," says Arrot.

The cyberinfrastructure will use a proprietary protocol to poll for sensor metadata such as sensor type, manufacturer, last calibration date and results, sample rate, resolution, conversion factors to engineering units, and 3D location. NEPTUNE (North East Pacific Time-Series Undersea Networked Experiments) will either use a broad, established standard or develop its own, according to McGinnis; if a broad, established standard that fits the bill is not already available, they will have to develop their own. The cyberinfrastructure will be complete in three or four years, according to McGinnis.

The Observatories

The observatories will allow researchers to collect, process, and interact in real time with this data, which now takes over a year to collect.

There are three kinds of ocean observatories, according to John Orcutt, professor of geophysics at Scripps Institution of Oceanography, University of California, San Diego, and the Principal Investigator for LOOKING for the NSF cooperative at UCSD.

• *Global observatories* — These are all buoyed observatories. They are anchored to the seafloor so they don't move around.

• *Regional observatories* — Mostly cabled with instruments floated from the seafloor with subsurface and surface buoys attached.

Figure 1 shows both subsurface and surface moorings as part of the Dynamics of Earth and Ocean Systems (DEOS) for the regional observatories. "The mooring is generally taut so the buoy doesn't move laterally a great deal. The mooring lines carry both power and communications to the instruments supported by the buoys. The picture is similar for the regional cabled observatory except the large, central buoy is not included and seafloor cables carry data and power into the site," says Orcutt.

• *Coastal observatories* — Mostly buoyed with some cabling proposed.

These geographical classifications (global, regional, and coastal) are characterized by their implementations (buoyed or cabled) out of practical necessity. According to Orcutt, for global observatories, it's generally too expensive to run a 2,000-2,500 km seafloor cable to a single site. The costs would consume all the funds available. The only practical way to do this is using a buoy with satellite communications capabilities on the surface.

For the regional cabled observatory, the costs of laying cable consume a large portion (maybe 40%) of the funds available to ORION, "so there is only one of these planned for now," says Orcutt. Coastal observatories require only short cable runs of about 100 km; "either buoys or cables (in a small number of instances) are possible for these," says Orcutt.

Some early observatories are being constructed off the US and Canadian western coasts. According to Alan D. Chave, senior scientist at the Woods Hole Oceanographic Institution, there will be observatories on the east coast as part of the OOI (Ocean Observatories Initiative, part of the ORION program, which will capitalize on new technical capabilities provided by the OOI. The LOOKING project is intended to serve the OOI by providing the cyberinfrastructure design.). The Regional Cabled Observatory (which is the first of its kind) will be off the Pacific Northwest. The existing observatories on the east coast are coastal, not regional.

Major observatories now in service include the Martha's Vineyard Coastal Observatory, the Long-Term Ecosystem Observatory (LEO15) off New Jersey run by Rutgers, and the Victoria Experimental Network Under the Sea (Venus) off the coast of Canada, according to Chave. These are all coastal observatories. These three observatories represent three instances of undersea sensor equipment connected through fiber-optic communication cables to onshore ocean research institutions that are connected to the high-performance research networks normally associated with "the Grid."

No observatories will be built with LOOKING project funds, however, as the purpose of the LOOKING project is simply to research and design the cyberinfrastructure that will manage the data from observatories. According to Chave, it may be that these observatories will use the product from LOOKING in a few years. These observatories were built with NSF and WHOI funds (MVCO), NOAA funds (LEO-15), and Canadian Foundation for Innovation funds (VENUS), explains Chave.

Planned US observatories include the Monterey Accelerated Research System (MARS) off the coast of Monterey, California, which will be installed later this year. According to Chave, the installation will include the F/O cable, which will be laid from the shore to the node location in 1,100 m of water and about 60 km from the coast. The node will be installed on the end of the cable. All of the systems to power and communicate with the node will be up and running and subsequently MARS will be commissioned after testing and tuning, adds Chave.

MARS will be a test bed for Neptune US, a regional cabled observatory in the northeast Pacific Ocean.

Service-Oriented Architecture

"Biological sensors remain a very big challenge," says Orcutt, explaining that, while there are acoustical and optical sensors that detect and identify biology, instruments that can actually sample and sequence DNA are largely still laboratory-bound. Physical measurements (current speed and direction, ground motion and temperature) are all easier to make and will be used broadly in observatories while we learn how to make chemical and biological measurements, adds Orcutt.

Researchers will eventually be able to sequence DNA and see changes in species concentrations over time. "It's an enabling technology we can build on for decades," includes Orcutt.

Neptune Canada (under construction) is two years ahead of Neptune US. "That will be deploying in 2008," says McGinnis. Neptune US, awaiting

> **"LOOKING and ORION are a part of worldwide research efforts to make data from the ocean depths freely and instantly available to land-based research institutions for grid computing."**

funding, should be complete by 2010, he adds, noting that the National Science Foundation is confident that it will be funded.

The cyberinfrastructure that results from LOOKING will provide power, communications, and resources that support a service-oriented architecture and distributed system, according to Chave. "It will enable a user at the University of Kansas, for example, to share instruments with a user at Scripps to put together their own virtual network of instruments for experimentation."

Data transport from all observatories will be transparent, he adds, so the user doesn't have to translate data between different formats from different observatories, says Chave.

Within the observatories, relative to the instruments, there are resource management services, the command and control interfaces, and a whole family of web services associated with operations, according to Arrot. Between the observatories, there are three fundamental services. One is for data products; how they are made available after you catalog the data. Then, the instrument services, a fundamental innovation created for ORION for the ubiquitous availability of data and interaction with the instruments. Finally, there is a governance layer that scopes who has access to what.

The LOOKING grid infrastructure will let researchers detect events such as volcanic eruptions, changes in surface temperatures in response to El Nino, and tsunamis in real time, according to Orcutt. They could even launch autonomous underwater vehicles on missions in response to real-time observations, he adds. This is a big advance over visiting ocean-sensing equipment by ship once a year to retrieve data.

Collected in real time, researchers can integrate the ocean's physical properties into oceanic and atmospheric models to predict sea conditions that can aid in missions such as search and rescue. Fiber-optics offer the chance to get images from the ocean bed that could help, for example, predict tsunamis, according to Mohamed A. Osman, a professor of electrical engineering and computer science at Washington State University.

With some observatories up and running, the physical infrastructure and data collection by automated ocean floor observatories are proven technologies. With the completion of the LOOKING cyberinfrastructure, we will be set to begin a new exploration of the other three-quarters of the world we live in. According to Osman, we know more about Mars and Jupiter than our own ocean beds. "It's time to understand how planet Earth works," Osman says. And, according to Orcutt, we can expect discoveries that we can't currently envision. "Until you can monitor things day in and day out for a period of years, you don't know what you can learn from it," Orcutt says. **NV**

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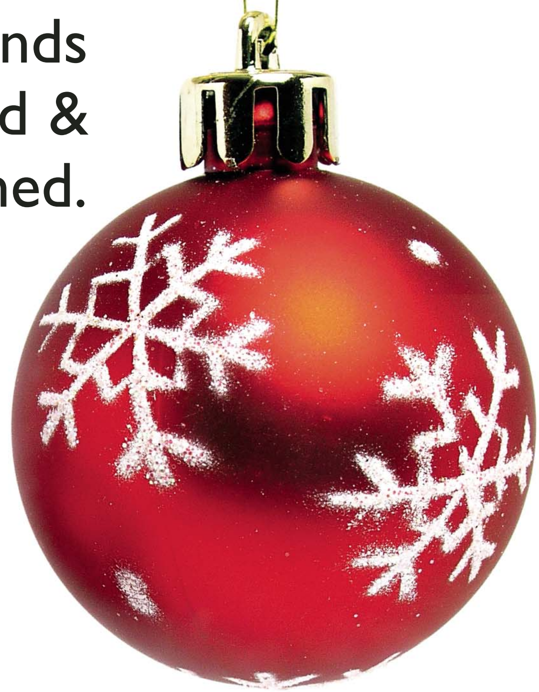

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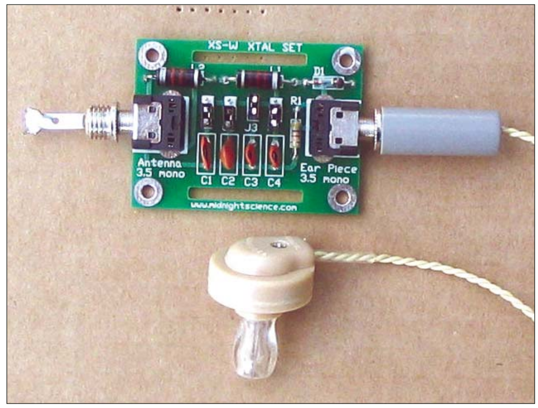
Continued from Page 30

NEW CRYSTAL RADIO KIT



The Xtal Set Society announces the availability of their newest crystal radio kit, the XS-W. The set is assembled on a 1.5 by 2.0 inch printed circuit board, small enough to wear on your wrist. An end-fed antenna and high-impedance ear piece attach to the PCB via 3.5 mm mono plugs to PCB-mounted jacks. A manual is provided, and solder assembly is required. For most hobbyists, kit assembly is less than one hour. Solder, tools, and antenna wire are not included.

The set uniquely tunes the AM broadcast band (550-1,650 kHz) via an array of capacitors jumper-selected on the PCB. These jumpers may be changed for tuning after assembly. Small size is achieved by using molded inductors for the main LC circuit and for antenna coupling. As with all crystal sets, operation is maximized when the set is grounded and attached to a sufficient antenna.

The XS-W Wrist Crystal Set Kit is $16.95 plus $4.95 shipping/handling.

Orders may be placed via the company catalog located on the website.

For more information, contact:
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DSP for the PC

— by Al Williams WD5GNR —

"Digital Signal Processing (DSP) has revolutionized how we design and build filters, signal generators, and other audio circuitry. Usually when you think of DSP, you think of specialized processors from companies like Analog Devices, Motorola, or Texas Instruments. However, practically every modern PC has a sound card that allows it to function as an audio DSP. With the speed of modern processors, a PC is up to nearly any audio task where you'd use a traditional DSP chip."

In some cases, a PC makes sense for the final form of a DSP application. But even if you will eventually target a "real" DSP, it is often more convenient to prototype and experiment on the PC.

In this article, I'll show you how to create DSP programs using an open source library available for Windows or Linux. I'll show you how to create sounds and process them using common TouchTones (technically DTMF or Dual Tone Multifrequency tones).

You'll need to download a few libraries and use your choice of C compilers. If you use Linux, you probably already have a C compiler. If you are a Windows user with no commercial compiler, you can use Cygwin, MinGw, or the Digital Mars compiler (see the references).

DSP Fundiamentals

DSP is a big subject. If you want to understand it, consider reading the free book from Steven Smith in the references. However, there are a few fundamental principles you should be familiar with:

• DSP programs sample their inputs (or produce their outputs) at a fixed time interval known as the sampling frequency.

• The highest frequency you can measure or produce is half of the sampling frequency. This is the Nyquist limit.

• As a practical matter, most DSP programs process a batch of samples at once. A program sampling at 8 kHz might process 1,000 samples at a time, corresponding to 125 mS of audio data.

In particular, PC programs usually process a buffer of audio data (samples) while another buffer is being collected (or created if you are producing audio).

Sound Card Interface

The open source PortAudio library works with Windows or Linux (and other platforms too). The stable version (V18.1) is easy to download. With a little more effort, you can get a "bleeding edge" version that is very similar, but fixes a few issues.

The idea behind PortAudio is simple. You set up a few parameters (sample size and buffer size, for example). Then you provide callback functions. When PortAudio has a buffer full of data, it calls your function. If you aren't listening for input, you don't have to provide this callback.

If you want to produce audio, you provide a different callback (of course, you'll often provide both in cases where your program both creates and processes audio). PortAudio calls this function when it needs more audio data to playback. For example, take a look at Listing 1, which shows a simple callback to produce a 1 kHz tone.

In Listing 1, the function computes the desired sine wave value

Listing 1

```
static int playCallback( void *inputBuffer, void *outputBuffer,
                         unsigned long framesPerBuffer,
                         PaTimestamp outTime, void *userData )
{
  static unsigned t=0;
  unsigned long n=0;
  SAMPLE *p=(SAMPLE *)outputBuffer;
  for (n=0;n<framesPerBuffer;n++)
    {
      p[n]=(sin(t++*2*PI*1000/SAMPLE_RATE));
      if (t==SAMPLE_RATE) t=0;
    }

  return 0;
}
```

based on the current sample time (t). Remember that t/SAMPLE_RATE will produce the actual time. That is, if you are taking 1,000 samples/second and the sample number is 100, then the "real time" is 100/1000 = 0.1 second.

If I were worried about memory or speed, I'd change how this function works. For example, the values could be from a table lookup; a sine wave table only needs the first quarter of the data (the other three-quarters can be easily computed). However, the PC has plentiful memory and horsepower so this is not necessary.

Generating DTMF

When you hear DTMF tones on your phone, you are really hearing two discrete tones (see Table 1). To create two tones, you simply compute two sine waves and add them together. You should, however, scale both sine waves to keep the output samples between -1 and 1. Listing 2 shows an example callback (the whole program is available online at **www.nutsvolts.com**).

Reading DTMF

So, creating tones is easy, but what about recognizing them? There are several different ways a program can detect tones. When recognizing a few well-known tones, the Goertzel algorithm is very efficient. However, a Fourier transform is a more widely-known technique and is far more flexible. To read DTMF, flexibility isn't required, but since you may want to do something more sophisticated than DTMF decoding, I decided to use the Fourier transform anyway. Besides, there are many more "off-the-shelf" Fourier transforms available because it is a more common technique.

The idea behind a Fourier transform is that it converts a time-domain signal into a frequency-domain signal. In other words, if you looked at an oscilloscope showing a 1 kHz sine wave, that's a time-domain signal. The same input to a spectrum analyzer would show a single "peak" at 1 kHz. That is a frequency-domain signal — a plot of frequency vs. amplitude instead of the more familiar time vs. amplitude plot of an oscilloscope. See Figure 1 for an example of an input signal transformed to the frequency domain (this shows a DTMF 8). The graph shows the magnitude of the transform, and you can easily correlate the peaks with the frequencies in Table 1.

When you compute the transform of a signal that consists of sample points, you end up with a number of "bins." Each bin corresponds to a band of frequency information. For example, suppose you take a half second of data at 8 kHz. That's 4,000 samples. The transform will result in 4,000 bins and each bin will represent 2 Hz (8,000/4,000).

Because of the Nyquist limit, only the first half of the bins contain meaningful data (in other words, the frequency bins above 4 kHz aren't usable). In fact, some libraries don't return the upper bins. The outputs of nearly all algorithms, though, are complex numbers. To effectively compare the "amount" of two frequencies, you must compute the magnitude of the result.

The magnitude is easy to compute; just add the square of each part of the complex number and then take the square root. For example, suppose you have a bin that contains a complex number with a real part of 9 and an imaginary part of 12. Simply add 81 and 144 to get 225. The square root of 225 is 15. So the relative amount of energy at the frequency corresponding to that bin is 15.

Writing a Fourier transform isn't very difficult, but optimizing performance can be challenging. Luckily, there are many readily-available libraries. I decided to use the GNU Scientific Library (GSL).

Like many libraries, GSL has its own ideas about the format of input and output data. Therefore, you may wind up writing some glue code to make everything work. Listing 3 (which is available on the *Nuts & Volts* website) shows the code for a simple DTMF decoder. The wrapper around the GSL library here (named fft) converts the PortAudio data into the data format that GSL expects. In addition, the wrapper then plucks the 16 bins of interest out and

Frequencies	1,209 Hz	1,336 Hz	1,477 Hz	1,633 Hz
687 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

TABLE 1. DTMF Frequencies.

Listing 2

```
static int playCallback( void *inputBuffer, void *outputBuffer,
                         unsigned long framesPerBuffer,
                         PaTimestamp outTime, void *userData )
{
  static unsigned t=0;
  unsigned long n=0;
  SAMPLE *p=(SAMPLE *)outputBuffer;
  for (n=0;n<framesPerBuffer;n++)
    {
      p[n]=0;
      if (frequency1!=SAMPLE_SILENCE && amp1!=0.0)
      p[n]+=amp1*(sin(t*2*PI*frequency1/SAMPLE_RATE));
      if (frequency2!=SAMPLE_SILENCE && amp2!=0.0)
      p[n]+=amp2*(sin(t++*2*PI*frequency2/SAMPLE_RATE));
      if (t==SAMPLE_RATE) t=0;
    }

  return 0;
}
```

computes the magnitudes. (Remember, the program averages adjacent bins, so to get the eight DTMF tones requires 16 bins).

As always, there are trade-offs involved in the design. Frequency resolution depends on the sampling rate and the number of samples. So, sampling at 8 kHz for 8,000 samples will provide 1 Hz resolution, but also requires a full second for sampling. A lower sampling rate or fewer samples allows for faster response times, but at the expense of frequency resolution. So, 4,000 samples requires a half second but resolves to 2 Hz per bin. Of course, you can also change the sample rate.

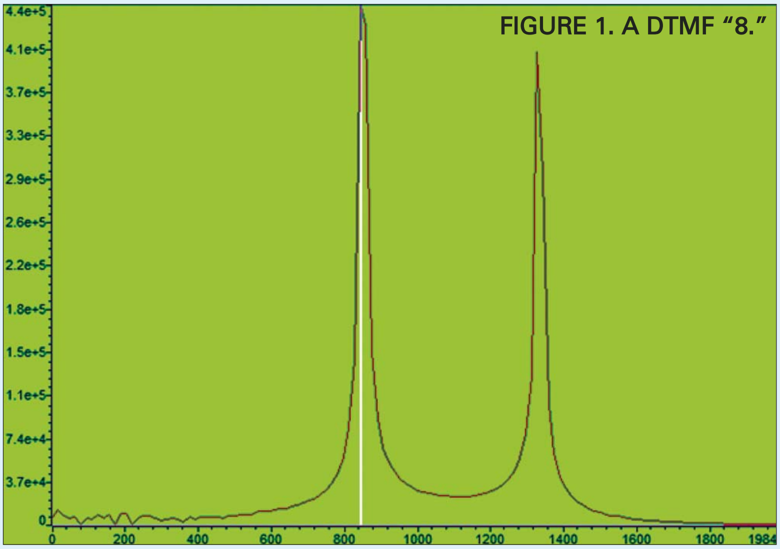

FIGURE 1. A DTMF "8."

At 4 kHz, a half second of data is only 2,000 samples, but the resolution is still only 2 Hz per bin — as usual, there's no free lunch.

Another consideration is the maximum frequency of interest. For DTMF, the highest frequency is less than 2 kHz, so the sampling frequency must be at least 4 kHz. If you were working with higher frequencies, you'd need a higher sampling rate. So, there is a complex interaction between the sample rate, the number of samples, and the minimum length of the tone (or tones) you want to detect (along with the space between tones).

For DTMF, there are formal standards that specify the minimum tone length and spacing, along with the minimum required signal strengths. However, I simplified the code so it has its own nonstandard requirements. The program takes 1,024 samples at 8,192 kHz. Therefore, each bin represents 8 Hz and the total time for each sample is 125 mS. Keep in mind though, that a shorter tone (say, 100 mS) will still provide enough data to trigger the algorithm.

To test the program, you can use the program that generates DTMF. Just set your sound card hardware to record from the sound card output (often called Stereo Mix in the mixer). If your sound card doesn't support this, you might have to hold a microphone up to your speakers. In any event, be sure you understand what source your sound card is "recording" from and have the gain turned up high enough. If things don't work, try recording the audio you are attempting to sample and listen to the playback. If the recording is weak or there is no signal, then you have a sound card setup problem.

Summary

With a few off-the-shelf libraries, it is simple to gather data from a sound card or even generate audio data. Advanced DSP techniques allow you to filter, analyze, and produce sound in a variety of ways. The decoder presented here is somewhat simplified (a real decoder would need to obey minimum tone time constraints, and should do some basic processing checks; for example, making sure the two tones are close to each other in strength and that no other tones are present). However, it can serve as a base for many similar programs, so I didn't want to add too much specific DTMF code to it. You could readily modify this code to decode Frequency Shift Keying, Morse code, or to identify a sequence of whistles.

Although you may normally only use a single operating system, the availability of cross platform tools means you can easily write code once and run it on multiple platforms. Even graphical programs can be portable with tools like wxWidgets (look online for more details).

So, next time you are faced with a DSP project, consider reaching for a PC instead of a specialized DSP system. The ease of development will certainly help prototyping and may even make the PC suitable for a final deployment. **NV**

REFERENCES

- *PortAudio* — **www.portaudio.com** Portable Audio Library
- *GSL* — **www.gnu.org/software/gsl/** GNU Scientific Library
- *Cygwin* — **www.cygwin.com** Linux-like Environment for Windows
- *MingW* — **www.mingw.org** Linux-like Compiler that Targets Windows
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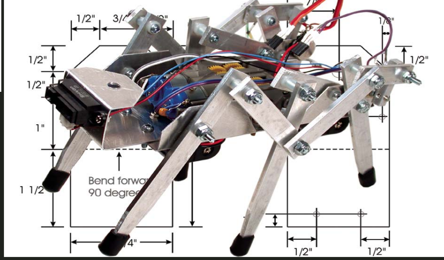
- *Fastest FFT in the West* — **www.fftw.org/** An Optimized FFT Library
- *Wikipedia* — **en.wikipedia.org/wiki/Goertzel_algorithm** A Wikipedia article that includes source code for a Goertzel DTMF decoder

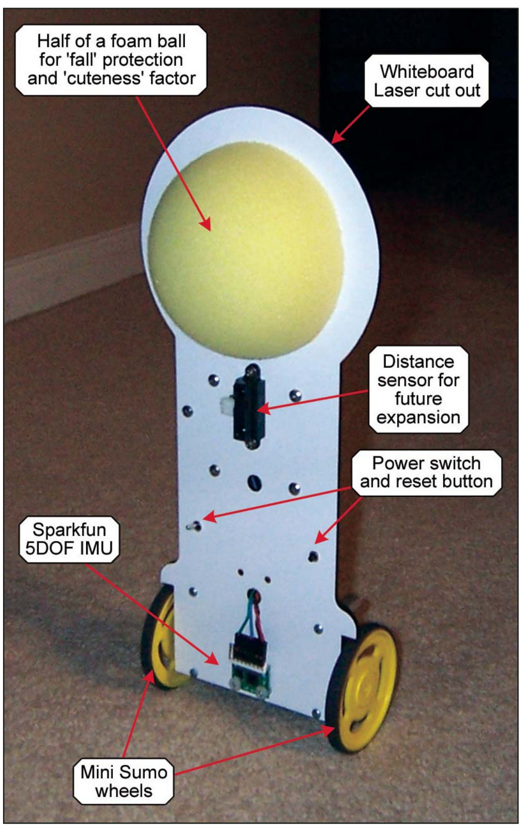


■ BY PHIL DAVIS and BRANDON HELLER

BUILDING A BALANCING BOT ON A BUDGET — PART 2: Making it Work

"IN THEORY, THERE IS NO PRACTICE. IN PRACTICE, THERE IS." For no project we've worked on has this statement rung so true! In Part 1 of this series, we covered the *theory* of a balancing robot, including sensor operation and PID loop balance control. In this part, we'll talk about the practice of building a balancing robot, including software techniques and careful tuning that overcame quirky, low-cost parts. Read more to find out how we got the robot to balance!

For those who missed the October issue, or anyone who could use a refresher, we'll start with a recap of the robot's design. See Photo 1 for a look at the finished robot, balancing.



■ PHOTO 1. Finished robot balancing on carpet.

THE ROBOT

The robot mechanicals are the ultimate in simplicity; the chassis is a single piece of whiteboard, chosen for its low cost, easy availability, and ability to be laser-cut. While the chassis could have been constructed by hand, laser cutting enabled curves which, when combined with a foam ball, lend it a unique personality. The robot's height creates greater rotational inertia, which slows down the rate at which the robot falls. A slower fall makes balancing easier, as the control system has more time to sense the tilt and react accordingly.

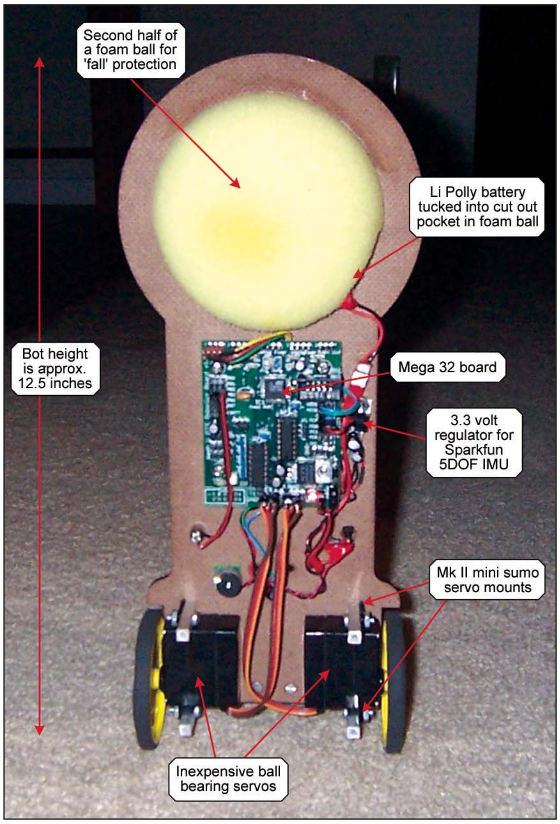
The current version of the robot uses standard-size GWS S03N 2BB servos. These servos are particularly easy to convert to continuous rotation; you only need to solder the motor leads to the servo cable, remove the h-shaped piece that links the output gear to the potentiometer, and clip the tab off of the final output gear. The square standoffs and mounting hardware from a Mark III mini sumo chassis kit provide secure servo mounts. Attached to the servos are standard 2-5/8" mini sumo wheels.

We use an Atmel AVR Mega32 control board with a TI SN754410 one-amp motor driver. This board was custom-designed for a class with mini sumo robots, and we are looking for a similar but more easily available version. The ADC inputs connect to a Sparkfun 5DOF IMU board, which includes an Invensense IDG300 dual-axis gyro and Analog Devices ADXL330 triple-axis accelerometer. We've used NiMH, NiCD, and LiPoly batteries in a relatively wide voltage range — from 8V to 18V — and all seem to work fine. A Matrix Orbital LK202-25-WB serial LCD set up for I^2C bus operation displays real-time data (see Photos 1, 2, and 3).

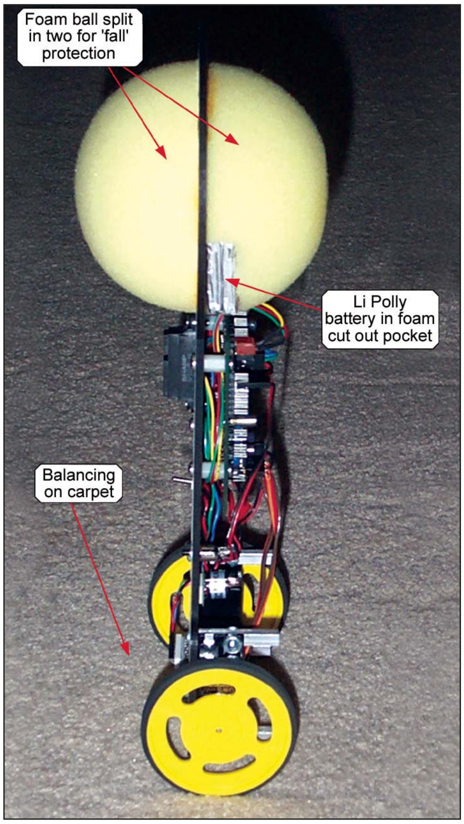
SOFTWARE IMPLEMENTATION

The program which balances the bot is essentially a single control loop which is called by a task executing at a precise timer interval.

The control loop portion of the code reads the sensors, fuses their values, and commands the motors. The code, while fairly complex, is not



■ PHOTO 2. Finished robot balancing — rear view.



■ PHOTO 3. Finished robot balancing — profile view.

particularly long. The control loop could have been called via a hardware timer and interrupts, but using a Real-Time Operating System (RTOS) simplifies the task of running the control loop at a precise interval. Remember that for the gyroscope to have an accurate estimation of tilt, it must be updated at a high rate, with an accurate indication of time. In addition, an RTOS lets us define tasks with different priority levels, and switches execution to the highest-priority task.

We chose FreeRTOS for the AVR, as it is freely available for many platforms, runs in our C development environment, and is well-documented. Look in the November issue of *SERVO Magazine* for a detailed review of FreeRTOS. (To order a back issue, go to **www.servomagazine.com**.)

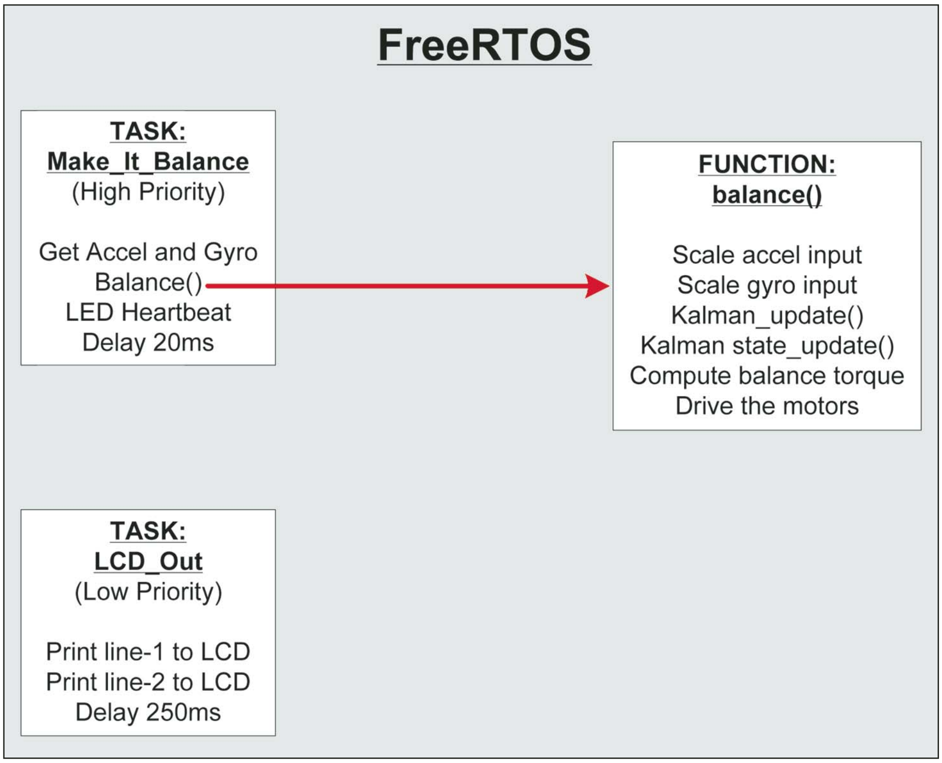
Using FreeRTOS leads to a surprisingly simple implementation, with only two main tasks (see Listings 1, 2, 3, and Diagram 1):

- "Make_It_Balance()"
- "LCD_Out()"

Two things must occur for the Make_It_Balance() task to properly balance the robot:

1) The task runs before any other task in the system. It must have the highest priority because, well, we want our bot to balance. If something else is going on and this task can't run, the bot will fall over. This is the beauty of a pre-emptive multi-tasking OS: It will *guarantee* that the highest priority task will run when it is able and ready to.

2) The task runs at a precise interval. The Kalman function, which fuses the two sensor inputs, depends on a fairly precise update rate. Using FreeRTOS we were able to set a timer, which lets us run the control loop at a precise interval. This particular type of timer will guarantee that our task will be run with accuracy within one tick. For the balancing bot application, we choose to configure the FreeRTOS tick to 5 ms. The Make_It_Balance() task is timed to run every four ticks (20 ms) which gives it a frequency of 50 Hz. If necessary, we can modify this to be



■ DIAGRAM 1. Functional chart of main tasks.

LISTING 1. Task Priorities

```
//    Tasks, variables and priority definitions
//
void Make_It_Balance(void *pvParameters);
#define Balance_TASK_PRIORITY       (tskIDLE_PRIORITY + 2)       //    Balance task
//
void LCD_Out(void *pvParameters);
#define LCD_Out_TASK_PRIORITY       (tskIDLE_PRIORITY + 1)       //    LCD output task
//
#define max_PRIORITY(tskIDLE_PRIORITY + 3)
```

100 or even 200 times per second, but sensor bandwidth and processor speed may then become bottlenecks.

The other main task — "LCD_Out()" — is more of an auxiliary or debugging task. As its name implies, it is used to output debug and status information to the attached Matrix Orbital LCD device. Consequently, we have the priority of this task set lower than Make_It_Balance(), because we don't care as much about the output to the LCD as we care about the bot balancing. We also set the frequency of LCD update to 50 ticks (250 ms) which is four times per second.

These are the main tasks which are scheduled to run by the OS. Now, let's talk in a little more detail about the structure of the actual control loop and the Kalman function which fuses the data from the gyro and the accelerometer. As we mentioned, Make_It_Balance() is run at a precise interval and, aside from the mechanics of setting the timer and toggling a heartbeat LED, it consists of three lines of code: a call to a routine which collects the sensor data, a call to 'balance,' and a delay.

```
for( ;; ) {
        read_accel_gyro();
        balance();
        vTaskDelayUntil(&LastWakeTime, TimeIncrement);
}
```

The vTaskDelayUntil() tells the FreeRTOS to run the task again at (LastWakeTime + TimeIncrement), ensuring our 50 Hz interval. The balance() function, which contains all the magic that enables our bot to balance, may be broken into several discrete pieces:

- **Scale the accelerometer input**
  - Convert to degrees from vertical, using the mG per mv constant, ADC input, and arcsin() function
- **Scale the gyro input**
  - Convert to deg/sec, based on the deg/sec per mv constant, ADC input, and gyro drift
- **kalman_update()**
  - Update angle and gyro drift with accelerometer reading
- **(kalman) state_update()**
  - Update angle (current_angle) and rate (current_rate) info with gyro reading
- **Compute motor outputs**
  - balance_torque = Kp * (current_angle - neutral) + Kd * current_rate;
  - Neutral is the natural balancing angle which may not be zero.
  - Kp is the proportional gain (the P in PID)
  - Kd is the differential gain (the D in PID)

LISTING 2. Make_It_Balance()

```
void Make_It_Balance(void *pvParameters){
      (void) pvParameters;                        //    The parameters are not used.

      portTickType            xLastWakeTime;
      const portTickType      xFrequency = 4      //    delay 4 ticks = 20 ms -- 50 times a second (5 ms ticks)

      cnt = 0;
      xLastWakeTime = xTaskGetTickCount();        //    Get base Clock Tick for delay timer

      // Cycle for ever
      for( ;; ){
            read_accel_gyro();                    //    read Accel and Gyro
            balance();                            //    main balancing act
            vTaskDelayUntil(&xLastWakeTime, xFrequency);     //    50 Hertz

            cnt++;                                //    Heartbeat...
            if (cnt % 6 == 0){                    //    Fast blink the LED when running
                  if (LED_ON)                     //    Good indication balance() is alive
                        Led(OFF);
                  else
                        Led(ON);
            }
      }
}
```

LISTING 3. LCD_Out()

```
void LCD_Out(void *pvParameters){
       (void)pvParameters;                                   //    The parameters are not used.

       // Cycle for ever
       for( ;; ){
              vTaskDelay(50);                                //    delay 50 ticks = 250 ms -- 4 times a second
                                                                   (5 millisec tick)
                                                             //    display LCD info 4 times a second
              sprintf(line1, "Ac %4.1f Gy %4.1f", (double) accel, (double)(gyro - q_bias));
              sprintf(line2, "An %4.1f Ra %4.1f", (double) current_angle, (double)rate);

              lcd_clear();
              lcd_print(line1);
              lcd_If();
              lcd_print(line2);
       }
}
```

- **Drive the motors**
  - left_motor_torque = balance_torque + steer_cmd;
  - right_motor_torque = balance_torque - steer_cmd;
  - set_left_motor_pwm(left_motor_torque + left_motor_bias);
  - set_right_motor_pwm(right_motor_torque + right_motor_bias);
  - The bias values are offsets required to get motors moving.

THE DEVELOPMENT ENVIRONMENT

As mentioned earlier, we choose to write the code for the balancing bot in 'C', using the free GNU GCC complier for AVR processors. The WinAVR distribution includes this compiler, plus many other libraries and tools, and can be downloaded from **http://winavr.sourceforge.net/**. This system comes with Programmers Notepad (PN, an editor for writing your C code), a wizard for generating your own custom makefile (used to compile), and some other useful bits and pieces including a pre-built library (AVR libc with source code) to simplify some common AVR hardware setup tasks. Rather than use Programmers Notepad, we use the integrated editor in Atmel AVRstudio, which can be downloaded from **www.atmel.com/dyn/products/tools_card.asp?tool_id=2725**.

These are two excellent systems which work very well together to provide a complete software development environment for the Atmel processors. There are two ways you can use this development system. One way is to develop all your code using PN, compile using a Makefile (still within PN), and then use AVRstudio to download the object (hex file) and debug. The other way (our preferred method) is to use AVRstudio as the editor/development environment, as well as the downloader and debugger. You can do this with the aid of a plug-in called avrgccplug-in which comes with all recent versions of WinAVR. With this approach, you never actually leave AVRstudio.

Two other features helped our development efforts greatly. These were:

- **JTAG Emulator**
  - Lets us step though the code and inspect variables, otherwise typically hard to do in a microprocessor environment like this.
- **Serial LCD from Matrix Orbital**
  - Displays critical balance variables in real time as the bot attempts to balance.

With the software setup out of the way, let's talk about how to calibrate the sensors.

CALIBRATION

Before any balance test, one must calibrate the sensors. Both our sensors have a noticeable bias, or voltage that represents no active signal. The accelerometer axis we use points forward when the robot is vertical, corresponding to zero G. This axis will have its highest resolution around zero degrees, and lowest at ±90 degrees offset. In other words, each ADC tick represents a much greater angle change near zero degrees. This property makes it easy to find the +90 and -90 degree values, especially with the LCD serving as a real-time display. The average of these two readings corresponds to a vertical robot (0 Gs of accel).

The gyro calibration is not strictly necessary, as the Kalman filter automatically tracks the drift, or deviation from original. It still helps, as a sanity check, to record an average of gyro values when the robot is not moving. This temporary gyro calibration value makes it easier to pick out the gyro drift on the LCD, which will be on the order of a few ADC ticks.

Lastly, we want to understand how much noise to expect with nothing else on, as well as with the motors moving. The on-chip ADC has error on the order of one 10-bit ADC tick, found by connecting a battery (an extremely stable voltage input) to an ADC input. The last test was disappointing; when the motors were running, the ADC inputs showed much greater variation. The Kalman filter acts as a low-pass filter to remove this noise. It should really be tuned for fast response, but we didn't find it necessary, and leave it to future work.

You'll also need to find the "neutral angle," the angle at which the robot balances, or more practically, the angle at which it falls forward and backward equally. The chassis design, wheel size, and battery weight all affect this angle. To get a rough value for it, use your hands to hold the robot near where it seems to balance, and watch the angle reading on the LCD. If this value is a little bit off, as it probably will be, you'll notice the robot tending to move forward in one direction. Adjusting the neutral angle .1 degrees at a time should get you close enough to optimal for it to stay in place.

GETTING IT TO WORK

Our first attempts at balancing used a bare minimum of hardware and software components, in the hopes of more easily discovering bugs. In the first test, the calibrated accelerometer provided a tilt input to a P loop. Of course, nobody expected this basic setup to work, and it didn't. The test *did* show the robot trying to move in the correct direction for balance, but revealed two problems. One issue was that the motors seemed to stop trying after about 10 seconds of balance attempts. Originally the robot had used a Tamiya dual gearmotor, and these larger motors drew too much current for the one-amp motor driver. As the motor driver would get hotter, it would enter thermal shutdown, and deliver current on the order of milliamps. The drop in motor current could be seen on an ammeter, as well as felt as a heat spike at the motor driver. The fix was a drastic one: We switched to servo motors and no longer had issues powering the driver.

The other issue was that the coarse granularity of the angle estimate at the time (.8° per ADC tick near balanced) seemed to delay the robot's ability to detect that it was falling over. To double the angle resolution, we switched the processor's ADC voltage reference input to the 2.5V internal reference. This change improved precision, but was clearly not enough; even with a .4° resolution, the noise was too high for consistent readings.

At this point, we added the Kalman filter, which fused the gyro and accelerometer readings to provide a more accurate estimate of tilt, one with an effective resolution of less than .1 degree. Unfortunately, the addition of the K-filter caused all the code to stop working. In FreeRTOS, each task has a fixed amount of stack space that it uses for temporary storage. The floating-point operations and function calls were overflowing the memory reserved for the balance task. Our simple fix was to increase the reserved memory for the stack, something we should have done at the beginning.

GETTING CLOSER

With the K-filter providing a much better angle estimate, we could now try balancing for real. The first parameter to tune is the P gain, which represents the control input per degree the robot is tilted. For example, a P gain of 200 corresponds to a control input of 100 when the robot is half a degree from vertical. We tried balancing with increasingly larger P values, up to 300, where the robot seemed to shake in place. We then dialed the P gain down to 200, which seemed to work well. Note that 200 is almost the entire range of control output; the eight-bit motor commands max out at 255. The robot could now balance for up to 10 seconds! Interestingly, placing the robot on a carpet made it work much better, and it could now balance for up to five minutes. The robot would rock back and forth in place, over a total angle of less than half a degree in each direction.

The next logical step would be to change the D gain to something other than zero. The D gain counteracts the P gain as the robot rotates toward zero; properly tuned, it should slow down or prevent the continuous back-and-forth rocking we were seeing. No such luck; even small D gains caused the robot to become unstable. Something wasn't right. It was as if there was a phantom lag in the control system.

ALMOST THERE

After much head-scratching, we noticed that the wheels wouldn't turn until about .2 or .3 degrees from neutral, but with the high P gain, they should've moved at lower angles. We then created a test for each servo, which would set the motor input to zero, and slowly increase it, while displaying the current value on the LCD. With a 10.2V battery, the servo started to turn at a motor input of about 60, corresponding to 2.4V. That's a disappointingly high number; it implies that one quarter of the motor input range is useless, and that there's a deadband where torque is zero for small angles. It explained the "rocking back and forth" issue.

For comparison, a small Escap — an expensive, high-precision motor — needed only .25V to begin rotating. That's an order of magnitude better! The fix — a piece of code to use motor commands in the range where they would cause the motor to provide useful torque — improved performance immediately, and the robot could now balance for longer periods with just a precisely tuned P loop. Now we could also tune the D loop, which eliminated the rocking issue and provided both damping near zero degrees and added resilience to external disturbance. In our case, this disturbance means poking the robot, and it's surprisingly fun. The D gain was raised slowly until the robot seemed most stable. The robot could now balance, on carpet, for nearly an entire battery charge.

FUTURE WORK

While the robot seems to balance nicely, we've identified some general principles of getting a robot to balance that motivate different component and design choices for a second version. Desirable characteristics include:

- Maximizing the platform inertia.
- Increasing the sensor signal-to-noise ratios.
- Using a motor geared for fast rotation and sufficient torque.
- Minimum control system latency.

Maximizing the platform inertia is as simple as moving the batteries higher or adding dead weight.

Increasing the sensor signal-to-noise ratios requires more care. One solution to reduce the noise would be to use separate motor and logic batteries, to prevent electrical noise generated by the motor windings from affecting sensor readings. Another solution is to use a low-pass filter at the sensor input, or do the equivalent in software by averaging the last n readings.

Aside from noise reduction, we could increase the signal swing by using an op-amp circuit as an amplifier, or switching to sensor parts that have a greater swing, often for a reduced total range. The robot should not be rotating much past zero degrees or rotating quickly, which makes ±1.2g accelerometers and 75 degree/sec gyros reasonable choices. The last solution, and probably most robust, is to switch to a sensor that has integrated signal conditioning and uses a digital interface to communicate with the main processor.

One example is the new ST LIS3LV02DQ, available from Sparkfun, which uses your choice of I^2C or SPI interfaces to return a 12-bit value. If you can supply it with a clean, filtered power input and connect the ground return directly to the battery ground terminal, it should provide low-noise sensor readings. This particular sensor can resolve down to 1 mG, or about 8x the resolution we get now with the lower-signal-swing ADXL330 and 10-bit internal ADC.

Finding the ideal motor gearing can be done through physics-based simulation, but it can be easier to just pick a motor that can move the wheels faster than we want. In our case, a standard servo motor worked reasonably well at higher voltages, but a little more speed and lower internal friction would be helpful.

Lastly, consider control system latency throughout the design of the entire system. In general, the higher the update rate, the smoother the balancing. High bandwidth sensors should be coupled with ADCs that make fast measurements. An RTOS, if one is used, should have a fast enough timing interval — in our case, 5 ms. There should also be minimal delay in getting a control value to the motor controllers. This issue motivated us to directly control the motors through PWM outputs, rather than use a serial motor controller. Software-correcting the motor deadband helped reduce the effective control system latency, although more expensive, lower-friction motors could be used, as well.

To improve the platform, a more rigid platform — made of stiffer material than whiteboard — would be nice. Encoders could help the robot hold its position against tilted ground or disturbances, or add the ability to move at precise speeds and distances. The use of carpet to help balancing is similar to using pneumatic wheels, in that the wheels contact a patch of ground, rather than a thin line like with the rigid servo wheels. We're looking into pneumatic wheels.

One last gripe: The control board is not publicly available, and we haven't found any online that are low cost, include a motor driver, and have a JTAG emulator port.

CONCLUSION

To recap, you can make a robust balancing robot on the cheap — for much less than $200, where most of the cost is in the sensors. We're not the first to do it, either. Both David Anderson's nBot, Larry Barello's Gyrobot, and jormorgand.net's Crunch are hobbyist balancing robots with plenty of additional detail available from their respective websites. Visit these sites or email the authors (phild2@charter.net) if you have any questions.

It works, it's fun, it's not too expensive, and the code is available at the *Nuts & Volts* website (**www.nutsvolts.com**). You should build a balancing bot! **NV**

RESOURCES

- nBot — **www.geology.smu.edu/~dpa-www/robo/nbot/**
- Autopilot project — **http://autopilot.sourceforge.net/gallery.html**
- Gyrobot — **http://barello.net/Robots/gyrobot/index.htm**
- Crunch — **http://jormungand.net/projects/crunch/**
- Sparkfun 5 DOF IMU — **www.sparkfun.com**
- Matrix Orbital I2C LCD — **www.matrixorbital.com**
- Rutherford Robotics has the bot chassis template and can laser cut it for you — **http://rutherfordrobotics.com/laser.html**

GETTING STARTED WITH PICs

THE LATEST IN PROGRAMMING MICROCONTROLLERS

BY CHUCK HELLEBUYCK

CHRISTMAS MUSIC

This month's installment marks the conclusion of the first year of this column. I want to thank everybody who reads these articles for their support. Since it's the December issue, I thought I would offer a project related to the holidays. I also wanted to tackle the subject of digital-to-analog conversion. To do that, I plan to have a PIC play a little Christmas music through a small speaker — kind-of like one of those Christmas cards that plays a tune every time you open it up. Should be easy enough, right?

DIGITAL-TO-ANALOG

We've covered how to read a resistance with an analog-to-digital port on the PIC, but what if you want to create an analog signal from a digital port on the PIC? It turns out that a simple capacitor circuit will do it. Actually, there are numerous complex circuits for doing this, depending on how accurate of an analog signal you need. If you were trying to reproduce a sine wave like those 12V to AC plug adapters you can buy to plug a laptop into your car, then you need some complex circuitry. To drive a simple speaker to make tones, you don't need much more than a series capacitor to form an integrator circuit.

Figure 1 shows the circuit I will refer to. The capacitor is a 10 µF electrolytic in series between the PIC I/O pin and an eight-ohm speaker. The speaker is the load and the capacitor rounds the square wave coming out of the digital PIC pin to form a very crude sine wave. By varying the frequency of the signal coming out of the PIC, we can produce different audible tones from the speaker. It won't be super loud but will be about the same loudness as those Christmas cards I mentioned. This project can also be handy to show how to give an audible feedback when a button is pressed or a warning is desired.

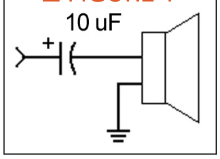
I also tried a magnetic transducer in this setup as a replacement for the speaker and it worked great. A magnetic transducer will make more of a vibration sound than a speaker, but we aren't trying to reproduce a symphony here. The advantage to the transducer is it's more robust and smaller than a speaker. I used one from **Jameco.com** part # 106500CK, but others will work.

TONE FREQUENCIES

I played musical instruments back in high school and I learned how to read music through that experience, but that didn't help me much with this project. One thing I didn't learn was the mechanics of music tones and how to produce them electronically. When I don't know, I go to the Internet to do a search. I found you can get nice, simple tone frequencies using what is known as the equal-tempered scale.

The equal-tempered scale has eight octaves of tones. An octave is defined by Wikipedia as the interval between one musical note and another with half or double the frequency. For example, middle C is the fourth octave and has the frequency of 261.63 Hz. To get the next octave, we would just double it to 523.26 Hz. We don't need that much accuracy, so we can just round these off to 262 Hz (C4) and 523 Hz (C5). For simplicity in the software, I chose to use the scale

FIGURE 1



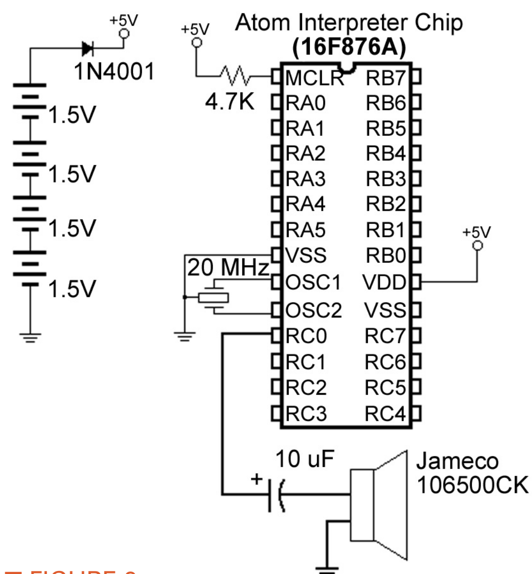


FIGURE 2

below based on parts of the fifth and sixth octaves and really only used five notes to create the *Jingle Bells* tune.

```
A con 440           setup values for various notes and
octaves
AS con 466          i.e. 466 = A sharp frequency, fifth
octave
B con 494
C con 523
CS con 554
D con 587
DS con 622
E con 659
F con 698
FS con 740
G con 784
GS con 831
```

HARDWARE

The hardware in Figure 2 shows the raw schematic based on the Atom interpreter chip, which is a PIC16F876A with the Atom bootloader inside. I actually developed this on one of my Ultimate OEM modules and then pulled the chip out and built the circuit around it to make it smaller and more portable. Being able to plug the programmed Atom chip into any PIC 28 pin 0.300" socket or blank board is one of the things I like about using the Atom. It makes it much smaller and a lot cheaper than buying $50 modules. Plus, I still get to use their great software and built-in in-circuit debugger. For the hobbyist on a limited budget, I can think of no better platform to use. I'm also in discussions with Basic Micro to get the readers of this column a better deal on Atom chips. I'll have more on this later.

I don't show a 5V regulator circuit since I used four 1.5V AA cells to drive it. They produce 6V, so I put a diode in series to knock it down to 5.3V, which is within the PIC16F876A's 2.0V-5.5V Vdd limit. The batteries will drop to 4.5-5.0V pretty quick anyway. This is a cheap way to power your PIC project.

ATOM SOFTWARE

This is a great opportunity to show the simplicity of the Atom Basic software again since it has the SOUND command built in to make driving the speaker at different frequencies very easy. In fact, I use this same setup in my book *Programming the Atom Microcontroller* to produce a *Mary Had a Little Lamb* tune. The code follows and is really quite easy to understand. This is another great example of the Basic language making something easy to implement in software. Let's step through the code to see how it works.

The first step here is to establish the frequencies and then give them a short nickname or constant in Atom Basic terms. I use the "CON" directive for each frequency.

```
'———————— Jingle Bells ————————————

A con 440           'setup values for various notes and
octaves
AS con 466          'i.e. 466 = A sharp frequency, sixth
octave
B con 494
C con 523
CS con 554
D con 587
DS con 622
E con 659
F con 698
FS con 740
G con 784
GS con 831
```

Next, the speaker connection is defined with a nickname and I establish two variables to count the notes and to store the notes to be played.

```
spkr con 8          'Speaker connected to PIC portc bit0
                    ' or port 8 in Atom
temp var byte       'Establish byte variable for For-Next
                    ' loop
temp2 var word      'Establish word variable for storage
                    ' of note to play.
```

Now, the main loop of code is entered and it's really quite simple. I use a For-Next loop to select each note for a total of 57 notes (0 through 56). Each note is selected from a lookup table using the LOOKUP command. On each new value of the "temp" variable, the LOOKUP command selects the frequency of the next note and stores it in the "temp2" variable. Then, the SOUND command plays that note through the speaker for 200 milliseconds. The NEXT command loops it back to get the next note. If a 0 is stored in "temp2," then a zero frequency sound is produced or no sound at all. I use this as a pause between notes. As you can see, I group several of these together to form a longer pause.

```
main
'**** This For-Next loop selects each note and plays it
using SOUND ***
for temp = 0 to 56
    lookup temp,[CS,0,CS,0,CS,0,0,0,CS,0,CS,0,CS,0,0,0|
    CS,0,E,0,A,0,B,0,CS,0,0,0,0,0,D,0,D,0,D,0,0,|
    D,D,0,CS,0,CS,0,CS,CS,CS,0,B,0,B,0,CS,0,B,0,0],temp2

    sound spkr,[200\temp2]       'Send note frequency to
                                 ' speaker
next                             'Loop back and get next
                                 ' note
```

The last note of the song needed a longer duration so I put it in its own SOUND command line. I could have used a variable for the duration of every note but that would have made the lookup table twice as long. I chose the easier way out.

```
sound spkr,[500\E]               ' Play last note
```

After the last note is played, the program simply delays for half of a second and then plays the tune again by jumping back to the "main" label with a GOTO command.

```
pause 500              'Pause half second and play the
                       ' tune again

goto main              'Jump to program beginning
```

As you can see, this is not a very difficult program to write. You can do a very similar program with PICBasic Pro if you have that compiler. The full software listing is available on the *Nuts & Volts* website at **www.nutsvolts.com**.

CONCLUSION

This was a fun little project to build and I even played "Name That Tune" with my son and daughter to see if they could tell what song it was playing. My son was quick to point out that the delay in the middle wasn't long enough, so I added more zeros. This helped, because my daughter who couldn't quite figure out the tune, started singing along after the change.

You could easily add several tunes to this on different LOOKUP command lines and then select which one by reading a switch or two. If you have the PICBasic Pro compiler, you can program a smaller PIC so it can be built into a plastic Christmas ornament or something small that can hang on the tree. How about adding a CDS cell tied to an A/D port so it plays the music every time someone walks by and blocks the light? Sound familiar? Christmas is loaded with these types of gadgets on the shelves and if you've been reading all the articles in this series, you know how to build your own.

Keep those emails coming. I have gotten some great tips on compilers from readers that I want to talk about in the future. And speaking of reader feedback, one common theme occurs every time I hear about the Atom. Most people that have used the Atom love it, but they don't love the price of the modules or even the less expensive Atom PIC chips. I took this feedback to the owners of Basic Micro and they are willing to hear me out.

Basic Micro gives away their compiler for free and makes their money on the hardware modules and boards. My point is hobbyists and basement professionals want a path to produce higher volume products without having to shell out $50 per design, and $20 Atom PIC chips just don't cut it either. There is always the pure .hex producing compiler route, but some people just don't want to spend all that money up front for a design that may only sell 10-50 units a year. Well it's not set in stone yet, but I may be announcing a discounted price for Atom PIC chips on my website, so stay tuned.

Happy Holidays to all the readers of *Nuts & Volts* and I'll see you next month as we start a whole new year of programming PICs. **NV**

■ BY LOUIS E. FRENZEL W5LEF

OFDM — ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

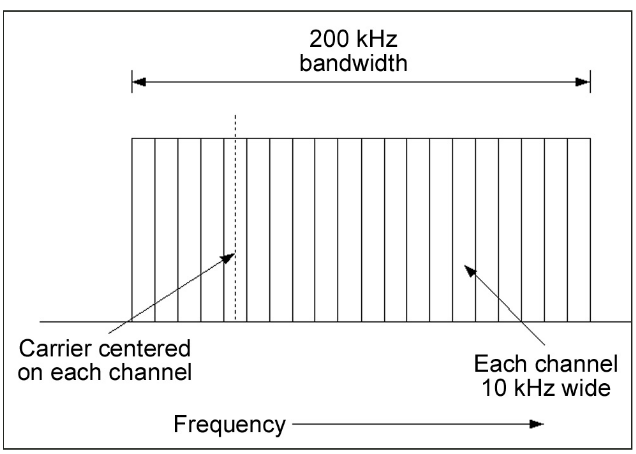
The Dominant New Wireless Technology is Changing the Way We Communicate

HAVE YOU HEARD OF orthogonal frequency division multiplexing (OFDM) yet? If not, your knowledge of communications techniques is definitely lagging behind the real world. Here is a quick look to bring you up-to-date on this wireless technology that is being adopted across the board in most new communications and networking systems.

OFDM is a sophisticated modulation and multiplexing technique that is being widely adopted in both new wired and wireless systems. It is very spectrally efficient in that it can produce a higher data rate in a given bandwidth than traditional modulation techniques. And its performance in microwave systems surpasses almost anything else in terms of robust performance in multipath environments. It comes close to being the ideal wireless method for digital data.

OFDM is a broadband modulation scheme that like spread spectrum or code division multiple access (CDMA) spreads its complex signal over a wide swath of bandwidth making it seem wasteful of spectrum space. However, using this technique, wireless systems can deliver faster data rates more reliably than with more traditional modulation techniques in narrow band systems.

OFDM is not new, having been discovered in the 1950s and 1960s. It has also been called multi-channel modulation (MCM) or discrete multitone (DMT). However, it has not been until the past decade or so that electronic hardware has become practical and affordable to implement it on a grand scale. Today, OFDM is readily available and cost-effective such that it is being adopted for almost all new communications applications, especially broadband wired and wireless systems. With that almost ubiquitous usage, you really need to know something about it.



■ FIGURE 1. The OFDM signal is multiple slow speed serial data streams that modulate individual carriers adjacent to one another in a common channel. Here, a 200 kHz channel is divided up into 20 sub-bands each 10 kHz wide. A carrier is centered on each sub-band. Each carrier is modulated by BPSK, QPSK, or QAM.

HOW OFDM WORKS

OFDM solves the age old problem of how to transmit faster data streams in a given bandwidth. There are physical limits using traditional modulation techniques as defined by Shannon's well-known law that data speed is proportional to bandwidth.

$$C = B \log_2 (1 + S/N)$$

Here, C is the channel capacity in bits per second (bps), B is the bandwidth in Hz, and S/N is the signal-to-noise power ratio.

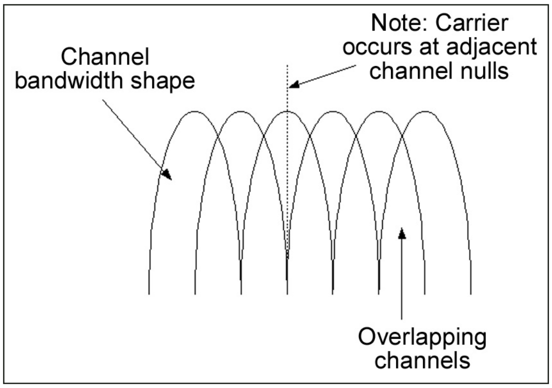
Multi-symbol methods where the bits to be transmitted change two characteristics of a carrier in the bandwidth have become popular to solve that problem. A good example is quadrature amplitude modulation

(QAM) where both the amplitude and phase of the carrier are changed to transmit multiple bits per symbol. A symbol is just one of several amplitude-phase combinations that represent multiple bits.

CDMA permits higher speeds by spreading the data over a very wide bandwidth. OFDM also uses a wide bandwidth, but in a different way. What OFDM does is generate many closely spaced carriers side-by-side in the spectrum. Then it divides up the high speed data to be transmitted into multiple, slower serial data streams and uses those to modulate the multiple carriers. The number of carriers depends upon the application, but can be less than 100 on up to several thousand.

Figure 1 shows what the OFDM signal looks like in the frequency domain. OFDM gets its name from the fact that it looks like a frequency division multiplexed (FDM) signal that puts multiple channels on a common bandwidth. A good example is the multiple channels on a common cable TV coax. A given bandwidth is divided up into channels or subcarriers sometimes called bins. Only a few subcarriers are shown here, but each has a carrier at its center with the surrounding channel width providing some spectrum for the sidebands created by the modulation. The carriers are frequency multiplexed into a wide channel, thus the name. The type of modulation can vary, but it is usually some form of phase shift keying like BPSK, QPSK, and even QAM.

The big question is how do you keep all the adjacent channels from interfering with one another? In the usual FDM application, the channels are spaced apart from one another with a so-called guard band between them. In OFDM, the channels are directly adjacent with no guard band.



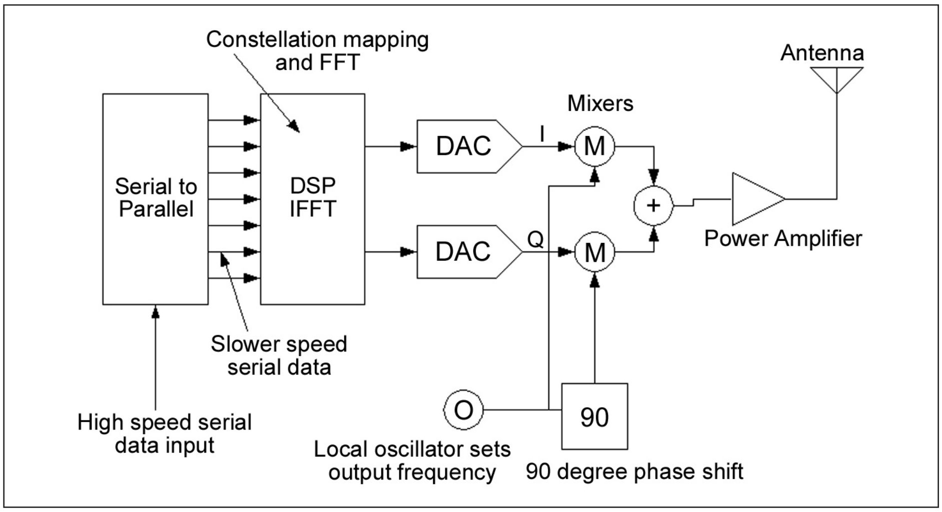
■ FIGURE 2. Each sub-band overlaps the adjacent bands. The signals in each are orthogonal such that the sidebands are nulled out at the adjacent carriers so they do not interfere with one another, making all signals recoverable at the receiver.

That is where the term orthogonal comes in. Orthogonal usually refers to two signals that are vectors 90 degrees out-of-phase. That means they won't bother one another and can be recovered individually when combined. In OFDM, orthogonal means that the individual carriers are spaced by a frequency that is the reciprocal of the symbol duration. What that means is that each carrier frequency will have an integer number of carrier cycles during one bit period of the data. The result is a spectrum that looks like that in Figure 2. Here, the spectrum response creates a null or zero at each of the adjacent carrier frequencies. With this arrangement, the individual modulated carriers can be recovered and demodulated without interference from one another.

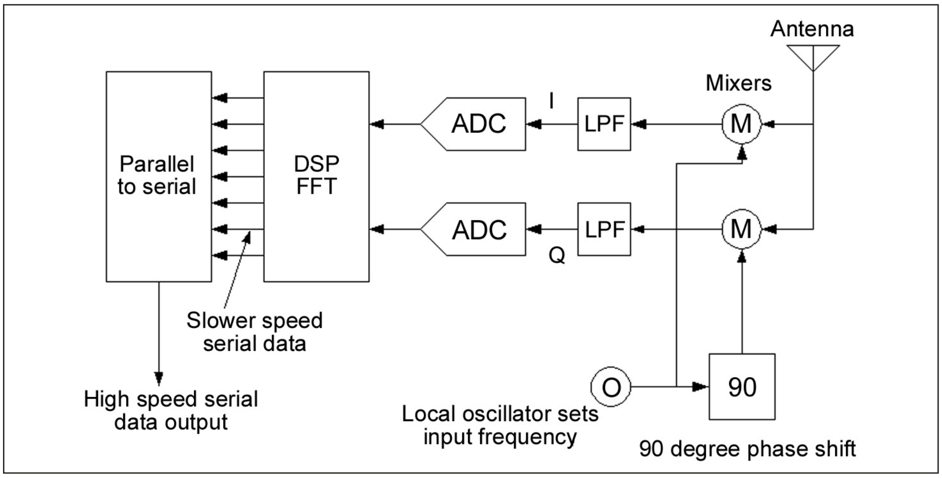
You are probably wondering just how all those carriers can be generated, modulated, then multiplexed on the output, then transmitted. At the other end, how do you demultiplex the carriers, demodulate each, and then recombine the slower data streams back into the fast data stream you started with? Assuming hundreds or thousands of subcarriers and the needed modulators and demodulators, the circuits would be alarmingly large and complex. Even with integrated circuits, it would be a daunting task to make all that circuitry work.

In real OFDM, the whole process is done with software on a digital signal processor (DSP). A special mathematical technique known as the fast Fourier transform (FFT) is used to convert a digitized OFDM signal back into individual demodulated carriers. An inverse FFT (IFFT) is used at the transmitter to generate the OFDM signal. Literally, the whole process is done with mathematical algorithms that run on a DSP. You simply program it to give you the desired number of subcarriers with the desired modulation.

Figure 3 shows the transmitter. The fast serial data is divided into hundreds or thousands of slower serial data paths. For example, a 100 Mbps serial signal could be divided into 1,000 channels each with a data rate of 100 Mbps/1,000 = 100 kbps.



■ FIGURE 3. An OFDM transmitter. The fast serial data is converted to slower parallel data streams that are processed by a DSP using the inverse FFT into multiple modulated carriers. The DSP outputs are translated into signals that are upconverted to the desired output frequency, then amplified and applied to the antenna.



■ FIGURE 4. This is an OFDM receiver. The signal from the antenna is downconverted to a lower frequency, filtered, and digitized by ADCs. The digital signals are then demodulated and the FFT in the DSP regenerates the original parallel signals. These are then reformed back into the original high speed serial data.

These serial data signals are then sent to the DSP where they are mapped to specific channels. The inverse FFT creates the multiple subcarriers which are then modulated. The OFDM signal appears at the DSP output as two digital words that are put through digital-to-analog converters (DAC) to form analog signal versions. These two signals are separated by 90 degrees to form what we call the in-phase (I) and quadrature (Q) signals. The I and Q signals are needed so that the receiver can recover the phase and amplitude components at the receiver. The I and Q signals are then applied to mixers to upconvert them to the transmit frequency. The result is applied to the power amplifier connected to the antenna.

Figure 4 shows what happens at the receiver. The OFDM signal is received by the antenna and usually passes through a low noise amplifier (LNA, not shown) and then to mixers where they are down-converted to a lower frequency. The low pass filters (LPF) remove the unwanted products of mixing. The resulting I and Q signals are then digitized by analog-to-digital converters (ADCs), then put through the FFT process in the DSP. The original subcarriers with modulation are recovered and demodulated to recreate the parallel data streams. These low speed streams are recombined into a single fast serial data stream carrying the original data.

One thing not shown here is the fact that OFDM is almost always used with additional channel coding such as forward error correction (FEC) and interleaving to reduce transmission errors. When those features are added, we call it coded OFDM or CODFM. It makes the signal less sensitive to fading and co-channel interference.

One final thing. While all those multiple carriers are only used to send one fast data stream, OFDM can be used to allow multiple signals to be carried over the same wide channel. It is the OFDM version of multiplexing and is called OFDM access OFDMA. For example, assume that a channel is made up of 1,024 subcarriers. By assigning each signal to be transmitted by 64 of these carriers, we can transmit 1,024/64 = 16 different signals. This technique is being employed in the newer fourth generation (4G) cell phone systems and in the new WiMAX broadband wireless systems.

THE BENEFITS OF OFDM

The primary benefits of OFDM as mentioned earlier are high spectral efficiency and insensitivity to multipath interference. With OFDM, you can squeeze more bits per Hertz (bits/Hz) into a given bandwidth. And because the signal is spread over a wide bandwidth with individual carriers, the overall signal is more resistant to noise and the fading and signal cancellation that occurs with microwave signals is reflected off of multiple nearby objects before they reach the receiver antenna. This characteristic is so good that some of the newer UHF and microwave wireless designs can actually be implemented with non line-of-sight antennas.

APPLICATIONS OF OFDM

Take a minute and try to name one or more everyday electronic products or systems you use that employs OFDM. Not sure? Here is a list of common uses today and some that are coming in the near future:

• *Digital Subscriber Line (DSL)* — If you have a DSL broadband Internet connection over your standard telephone line, you are using OFDM. In a DSL system, OFDM is referred to as discrete multi-tone (DMT). It puts the high speed downstream data on 256 carriers above 138 kHz on the twisted pair telephone line. Each carrier is 4 kHz wide and modulated by some form of QAM, depending upon the desired data rate.

• *Powerline Modems and BPL* — Some home networking equipment transmits high speed data over the AC power lines. The OFDM signal just rides the 60 Hz, 120 volt sine wave from outlet to outlet so no new wiring is needed. A larger scale version of this is called broadband over powerline (BPL). Electric utilities in some parts of the country offer broadband Internet connections by transmitting the OFDM signal over the high voltage transmission lines. BPL causes the high frequency signals to be radiated from the power lines which can cause horrible RF interference to many radio services. It is not a popular broadband method.

• *Digital Radio* — The new high definition (HD) radio now being transmitted by over 700 stations in the US uses OFDM. HD radio expands the audio frequency response of both AM and FM radio and transmits higher quality audio by putting OFDM signals in the expanded sidebands. OFDM is also used by European digital radios. Called digital audio broadcasting (DAB), OFDM is at the heart of the Eureka-147 system in the VHF bands and the Digital Radio Mondiale (DRM) system used in the shortwave bands (3 to 30 MHz).

• *Wi-Fi Wireless LANs* — The most popular wireless local area networks (WLANs) known as Wi-Fi use the 802.11a/g standards that specify OFDM to achieve a data rate to 54 Mbps in the 2.4 GHz band (802.11g) and the 5.8 GHz band (802.11a). Wi-Fi is widely used in home and enterprise LANs and in laptops to access hot spots around the world.

• *WiMAX* — WiMAX is the new broadband wireless technology that is being adopted for high speed Internet access as an alternative to DSL and cable TV access. It transmits in the 2.5, 3.5, and 5.8 GHz bands and can achieve data rates to 70 Mbps in back haul use, but lower rates for home and business Internet access. Based on the IEEE 802.16 standard, OFDM is at the heart of the technology.

• *Ultra-Wideband (UWB)* — UWB is a short range wireless technology designed for transmission of high speed data in home and office networks. A primary target is wireless video transmission in homes. It uses OFDM to achieve a data rate to 480 Mbps, up to 10 meters in range.

• *Long Term Evolution (LTE)* — LTE is the name given to fourth generation (4G) cell phones by the Third Generation Partnership Project (3GPP) group responsible for developing and standardizing cell phone technologies for the International Telecommunications Union (ITU). LTE uses OFDM to give data rates to 20 Mb/s on cell phones in a mobile environment. LTE is a few years off but it is expected to be widely adopted.

• *Digital Video Broadcast (DVB)* — DVB is the name of Europe's digital television standard. The terrestrial version (DVB-T) used COFDM. So does the new mobile or handset version (DVB-H) that will deliver TV to cell phones. At one time, the Advanced Television Standard Committee (ATSC) considered changing the the modulation scheme of the US's high definition TV standard from 8VSB (eight level vestigal sideband) to CODFM, but in the end, it was not.

OFDM is complex, mathematical, and impractical for casual experimentation. But it is so good that it is the king of wireless at the moment. It will be used in all but the simplest wireless applications in the future. **NV**

BY PETER BEST

ZIGBEE FOR THE EVIL GENIUS

OOK (ON-OFF KEYING) MODULATION used in simple AM data radios is also a popular and inexpensive way to move small amounts of data between points A and B. Move up the stairs a few steps and you'll find 802.11, which comes equipped to utilize the Internet protocols to form and maintain a network. If you're using simple AM or FM data radios in a network, you'll have to code most all of the application and network stuff yourself as you're simply pumping bits out across the airwaves. That's fine as most of the time OOK-based networks are very simple, two-node affairs and most of the OOK radio manufacturers bundle in software to augment the operation of the radios.

The latest network craze is called ZigBee. ZigBee actually takes the best of the simple OOK network and blends in some of the automatic networking ability of 802.11b. This is accomplished using what is called a ZigBee stack. Trust me. You'll have to put in some time to understand and digest a typical ZigBee stack. However, it's not an impossible feat. A ZigBee stack empowers a ZigBee network to form up and maintain itself with very little or no outside intervention. For instance, if you want to add a node to a typical OOK-based network, you will have to had already anticipated the node's addition and added the node's support code early in the design phase. Otherwise, you write the code on the fly to accommodate the new node. Adding a node to a ZigBee network is as simple as turning on the new node within radio range of the network you wish the node to join.

I have no intention of bashing ZigBee stacks in this column. In fact, I'm fascinated with the thought processes that have gone into the engineering of ZigBee hardware and the ZigBee stack specification. However, did you know that you don't really need a ZigBee stack to move data in a ZigBee kind of way?

In reality, a ZigBee stack is simply a layer of functionality that rides on an IEEE standard called 802.15.4. The ZigBee stack mechanism is in place to allow all of the ZigBee players' ZigBee devices to interoperate. For instance, a 2.4 GHz IEEE 802.15.4-compliant transceiver made by Microchip is able to communicate with a 2.4 GHz IEEE 802.15.4-compliant transceiver manufactured by Atmel because both radios follow the same laws laid down in the IEEE 802.15.4 standard.

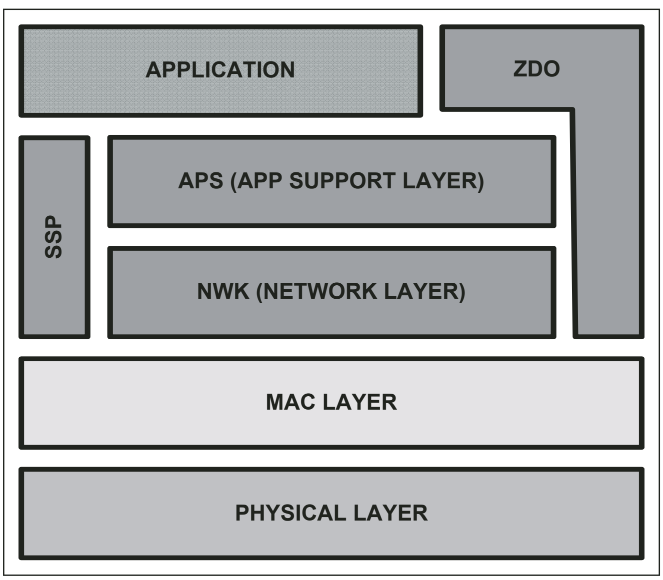


FIGURE 1. Put simply, every layer above the MAC layer is ZigBee. The MAC and PHY layers are governed by the IEEE 802.15.4 standard.

Likewise, application and network elements within the Microchip and Atmel ZigBee stacks can also communicate as peers as they are governed by the rules set forth by the ZigBee Alliance. If you're going to manufacture a ZigBee device, compliance is very important to interoperability. However, by simply utilizing IEEE 802.15.4 standard methods, you and I can effectively move small amounts of data wirelessly over short distances without having to license the radios or depend on the services of a ZigBee stack.

ZIGBEE 101

Honestly, it would take up the entire magazine and then some if we were to engage in a full discussion of the ZigBee protocol and the IEEE 802.15.4 standard. So, we will concentrate on what matters to us — the movement of small amounts of data over a wireless medium using only the mechanisms provided by IEEE 802.15.4. Figure 1 is a graphical representation of the components that make up a typical ZigBee stack. There are some things ZigBee you need to understand to be able to understand things IEEE 802.15.4. Keep in mind that ZigBee is not IEEE 802.15.4 and IEEE 802.15.4 is not ZigBee. They are two separate but complementary entities. IEEE 802.15.4 is the means by which ZigBee travels. So, let's quickly work our way from the top to the bottom of a ZigBee stack.

The Application Layer (APL) is simply your program if we look at a ZigBee stack in terms of a microcontroller. However, in a ZigBee point-of-view, the APL is a combination of multiple application objects contained within an Application Framework (AF), which are supported by what are called endpoints. In simple terms, an endpoint is the unique address and data portal for application objects. Application objects are defined by manufacturers.

The ZigBee Device Object (ZDO) defines the role of a device in a network. There are two common ZigBee devices that you've probably heard lots about. They are the ZigBee Coordinator and the ZigBee End Device. The ZigBee Coordinator is the king (queen for the ladies in the audience) of a ZigBee network as it is responsible for forming the network and allowing ZigBee End Devices to associate with and ultimately join the newly-formed network. The ZDO's job responsibilities also include discovering devices on the network and fishing out the application services that the devices provide.

The Application Support Sublayer's (APS) claim to fame is its ability to maintain binding tables. Between you and me, I hate figuring out and coding tables. However, in this case, the concept behind the elements contained within a binding table are easily grasped. A bind is actually a logical connection between two devices that is based on their services and needs. Once the devices are bound to each other, messages can be passed between the devices without any additional routing or addressing overhead. A simple example of binding occurs when a particular switch among a number of switches on a ZigBee End Device is bound to one of several LEDs on the ZigBee Coordinator.

NWK is short for network. The NWK layer is coded to allow a device to join or leave a network and route frames to their intended destinations. As far as the ZigBee Coordinator is concerned, the NWK layer is responsible for starting a new network and assigning addresses to newly associated devices when appropriate.

The MAC sublayer is in charge of any operation that involves the physical radio channel. In addition, the MAC is responsible for the following tasks:

• Providing a reliable link between two peer MAC entities.

• Handling the CSMA-CA mechanisms for channel access.

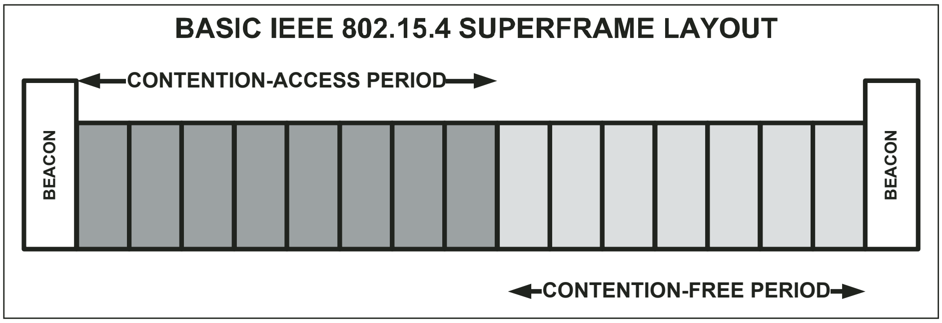
Don't get too excited about the acronyms I just rattled off. Just remember that the MAC uses CSMA-CA (Carrier Sense Multiple Access – Collision Avoidance) to check the channel for traffic before it tries to transmit. The MAC also verifies that incoming packets are really intended for the device the MAC is representing. The MAC offers other services such as beacon management in time-frame-based networks and the automatic acknowledgement of certain frame sequences. Beacon-oriented networks issue periodic beacons that enclose superframes.

A beacon is an informational packet that advertises the rules that the network has established and uniquely identifies the PAN (Personal Area Network) by divulging the PAN's ID and capabilities. PAN in IEEE 802.15.4 and ZigBee is synonymous with WLAN (Wireless Local Area Network) in 802.11b. A minimal PAN consists of a coordinator and an end device. You may also have a coordinator coupled with FFD (Full Function Device) and an end device associated with RFD (Reduced Function Device).

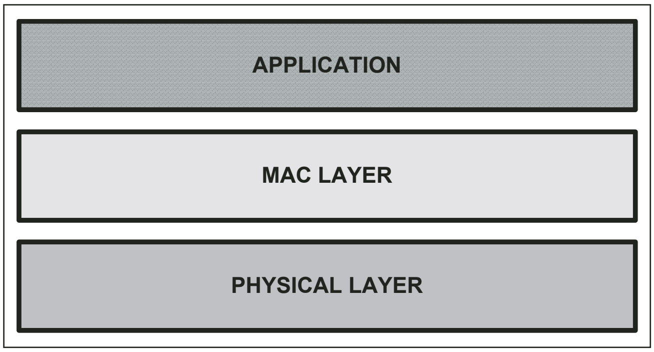
The time between successive beacons is called a superframe. A superframe is simply 16 time slots with a portion of those time slots optionally allocated as guaranteed time slots or GTSs. A GTS is dedicated to a particular time-sensitive application that must be able to communicate during every superframe period at the same time within the superframe period. Only devices specified to operate in the GTS time slots can access the medium during GTS time.

The remaining superframe slots are free-for-all time periods that allow every device that can gain access to the medium within the allocated free-for-all time using standard CSMA-CA mechanisms to do so. Think of the free-for-all superframe slot time as operating like a normal Ethernet network. The free-for-all time period within the superframe is called the CAP (Contention-Access Period). The GTS time slots make up the CFP (Contention-Free Period).

A superframe begins with a beacon, which is followed by a CAP, which is followed by a CFP. The end of a superframe and the beginning of a



■ FIGURE 2. The beacon order number determines the time that will elapse between successive beacons. The superframe order is used to specify how long the 16 slots between the successive beacons will persist. Thus, when the beacon order is equal to the superframe order, the 16 superframe time slots are taking all of the time available between the beacons.



■ FIGURE 3. You can't get close to a ZigBee implementation with this lineup. However, with a little bit of extra coding effort, you can send and receive meaningful data with the help of the IEEE 802.15.4 services contained within the MAC and PHY sublayers.

new superframe is defined by the emission of a periodic beacon. If none of the devices on a slotted (beacon-enabled) network require a GTS period, the entire superframe can be formatted as a CAP. Networks that do not utilize beacons are called unslotted networks. Since there are no beacons in an unslotted network, there are no superframes and thus no superframe slots. A basic superframe is modeled in Figure 2.

Unlike any other stack layer, the Physical Layer (PHY) is composed of both logic and hardware. Part of the PHY is code while the other piece of the PHY is radio hardware. You will see some IEEE 802.15.4 radio manufacturers provide a HAL (Hardware Abstraction Layer), which is firmware that adapts the physicals of the radio interface to the logic and hardware that supports the PHY. A HAL allows the manufacturer's radio to interface to most any hardware as the I/O structure between the radio and supporting hardware can be customized to accommodate the situation. The PHY is responsible for the following tasks:

• Data Transmission and Reception.

• CCA (Clear Channel Assessment) for CSMA-CA (Carrier Sense Multiple Access – Collision Avoidance).

• Activation and deactivation of the radio transceiver.

• ED (Energy Detection) within the current channel.

• Channel frequency selection.

• LQI (Link Quality Indicator) for received packets.

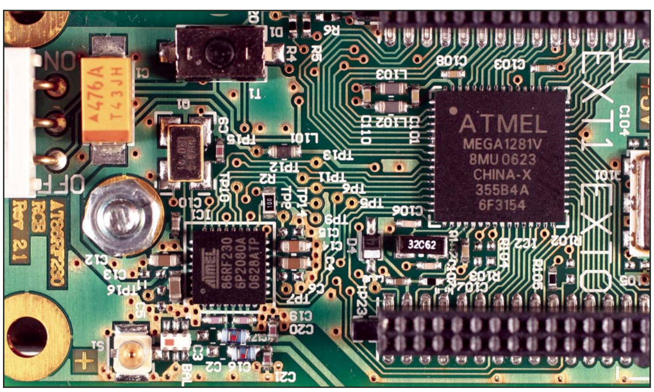
Two PHYs — 868/915 MHz and 2.4 GHz — are defined by the IEEE 802.15.4 standard. Both bands reside in the license-free ISM (Industrial Scientific and Medical) spectrum. Everyone in the world can play in the 2.4 GHz band while only Europeans can legally use the 868 MHz frequency range and North America has the privilege of accessing the 915 MHz band. To that end, the IEEE 802.15.4 standard is designed to conform to established regulations in Canada, Europe, Japan, Israel, and the United States.

All of the stack sublayers we've discussed are connected logically by SAPs (Service Access Points). There are two types of SAPs. Data is passed between layers using data SAPs and management messages are passed through management SAPs. In actuality, data structures representing the service to be provided are filled with the necessary information and passed between the layers. The receiving layer code acts on the received data structure and acts accordingly. The receiving layer may simply execute some code to provide a service or use the passed information to prepare a service data structure that will be passed to an upper layer for processing.

The data structures that are passed via the SAPs are called primitives. Each primitive has a specific service it represents and a particular set of data within it to help make that service happen. Primitives don't actually do any computing on their own. The services within each layer use the primitive data to carry out the service associated with a particular primitive.

Forget about the SSP block in the ZigBee stack. We won't be using any of the ZigBee stack security features. While we're on the "forget about it" boat, you can also wipe the layers above the MAC up to the APL out of your mind for now, as well. We won't be doing any dedicated ZigBee stack stuff in this session either. The layers shown in Figure 3 are all we care about for now.

Basically, we will be discussing the IEEE 802.15.4 mechanisms that are implemented within the Atmel AT86RF230 ZigBee/IEEE 802.15.4-compliant 2.4 GHz transceiver you see in Photo 1. I've given you a very brief overview of ZigBee and IEEE 802.15.4. Let's expound on that basic knowledge and examine the code used to transfer some bits between a coordinator and end device on an IEEE 802.15.4 network.



■ PHOTO 1. It looks easy from here. If you are capable of doing so, Atmel provides a full set of Gerber files and a parts BOM so that you can make one of these yourself. The AT86RF230 units are powered by a pair of AAA alkaline batteries, which are mounted on the other side of the module.

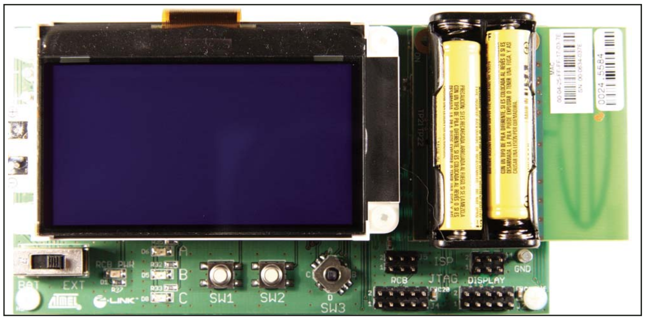
THE ATMEL AT86RF230

Low power, low cost, IEEE 802.15.4-compliant, and ZigBee-ready are all words that describe the Atmel AT86RF230 IEEE 802.15.4-compliant transceiver. The idea behind the AT86RF230 is to provide a building-block path between a microcontroller's SPI port and the radio antenna. Typically, RF design is black magic that is left to those that are in league with the beings of the underworld. In the case of the AT86RF230, all of the critical RF components with the exception of the antenna, crystal, and decoupling capacitors are integrated into the AT86RF230 chip.

The AT86RF230 modules I will be showing you came as part of my Atmel ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit. In addition to five ATmega1281V-based AT86RF230 transceiver modules, the ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit includes a master module that is equipped with a dot-matrix LCD and a socket for an AT86RF230 transceiver module. The ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit master module also provides hook-ups for programming and debugging the master module's ATmega128 and the AT86RF230's ATmega1281V using an Atmel JTAGICE mkII or the ATAVRISP mkII programming dongle. The ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit comes with an ATAVRISP mkII programming dongle. The ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit master module is posing in Photo 2.

There aren't many words I can put around the AT86RF230 without simply quoting the AT86RF230 datasheet. A standard SPI arrangement and four general-purpose I/O connections are all you need to control the AT86RF230. All of the schematic diagrams for the ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit can be had from the Atmel website. So, there's no reason to post them here. However, Figure 2 rounds up the simplicity offered by the AT86RF230 hardware.

Before we move on to the firmware portion of this edition of Design Cycle, I suggest downloading the ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit schematic package from the Atmel website. That will give you the full monty on the ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit hardware hook-ups. All you need to know right now is that each AT86RF230 is loaded with three LEDs attached to PE2, PE3, and PE4 of the ATmega1281V. There's also a pushbutton switch on each AT86RF230 attached to PE5. There is nothing remarkable about the rest of the AT86RF230 circuitry as the ATmega1281V is connected to general-purpose I/O and clock sources in standard microcontroller fashion and the AT86RF230 portion of the transceiver module schematic is filled with bypass capacitors. Don't get me wrong. That's a good thing. Let's not complicate things that we don't have to. The whole idea behind ZigBee and IEEE 802.15.4 is low cost and ease of use.



■ PHOTO 2. The master module's ATmega128 is in charge of the LCD, as well as the AT86RF230 module piggybacked on the right. The master module can be battery powered or plugged into the wall wart that comes with the ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit.

LOOK, MA, NO STACK!!

Well, sorta. We're only going to depend on the pair of sublayers that are defined in the IEEE 802.15.4 standard. The ZigBee APL and technically some of the ZigBee NWK sublayer tasks will be performed within our AVR MAC code, which was graciously provided by Atmel as part of the ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit.

In keeping with my promise to provide you, the *Nuts & Volts* reader, with inexpensive and useful projects within the Design Cycle pages, thus far, the only expense you would have incurred is the cost of the ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit itself. Many of you are avid AVR fans and if you already own an Atmel STK500/STK501 development system, you can also get AT86RF230 functionality by purchasing an ATAVRRZ502 IEEE 802.15.4/ZigBee RF Accessory Kit, which puts an AT86RF230 transceiver on your STK501 expansion board.

There are no compilers to buy as you can download and use WinAVR (free) or download and install the 30-day demo version of the IAR Embedded Workbench for Atmel AVR, Evaluation Version v4.20A. There's an include entry for ICCAVR in the Atmel source, which points one to the inexpensive and powerful ImageCraft AVR C compiler. I didn't test the Atmel code using ICCAVR. However, I didn't see anything that would keep ICCAVR from being used successfully with the code that Atmel provided with the ATAVRRZ200 IEEE 802.15.4/ZigBee Demonstration Kit.

You can also get the Atmel MAC code we're about to examine free for a download from the Atmel site, as well. Let's get on with our walk through the IEEE 802.15.4 MAC application, which is realized in Listing 1 (available on the *Nuts & Volts* website at **www.nutsvolts.com**).

The initial #include statements pull in all of the necessary IEEE 802.15.4 constant and type definitions that correspond to the IEEE 802.15.4 standard. You'll find primitive definitions in the wpan.h include file. Studying the contents of the #include files will shed lots of light on IEEE 802.15.4 and primitives.

I chuckled at the PAN definitions in the Macros area of the Atmel MAC code. The cool thing about those definitions is that they stand out in an IEEE 802.15.4 trace. Short addresses in IEEE 802.15.4 are 16 bits in length. An official IEEE 802.15.4 address is 64 bits in length. Short addresses are used to conserve power by reducing transmission time and save space in the frame by eliminating the need to transmit 64-bit addresses. There are only 127 total bytes allowed per IEEE 802.15.4 frame. Note that the beacon order and superframe order definitions are set for decimal 15. That disables the emission of periodic beacons and thus eliminates superframe generation, which means this will be an unslotted network. We could create a slotted network by reducing the superframe order and beacon order values below decimal 15.

The Typedefs area provides us with the data structures that ultimately provide the definitions of the association table and status variables. Note the states that are enumerated in the coord_state_t typedef. These states are important as they help guide the flow of the Atmel MAC firmware's task execution.

The functionality provided by the Atmel MAC firmware is contained within a library file that we can access using API calls that are named after the primitives they represent. The Atmel MAC code requires that we constantly call wpan_task as fast as we can as wpan_task is in control of dispatching and servicing the tasks contained within the library. Any API call beginning with wpan is aimed at the library and if any action generated by the API call needs to be handled by the Atmel MAC code, it will be given back to us in a callback function that begins with the user.

For instance, follow the execution of the mac_do_reset function. The first thing the mac_do_reset function does is place an API call to wpan_mlme_reset_request(true). The mlme in the call stands for MAC Layer Management Entity, which is the management part of the MAC layer that is accessed via the management SAP. We have effectively passed a primitive to the MAC's management area asking for a reset of the MAC. So that we can know what we did last and the program flow knows what was done prior, the state machine's state is changed from INIT_DONE to PEND_RESET. Our callback function is usr_mlme_reset_conf (uint8_t status). The conf is short for confirm, which is another word in the primitive language.

Let's pretend that things went as planned and the status returned by our wpan_mlme_reset_request(true) API call was MAC_SUCCESS. We have previously set the new state to PEND_RESET, which satisfies the "if" statement in the usr_mlme_reset_conf (uint8_t status) callback function and invokes the mac_set_short_addr(PANCOORD_SHORT_ADD) function, which sets the PAN coordinator's address to 0xBABE. In the process, the state machine's current state gets changed to PEND_SET_SHORT_ADDR within the mac_set_short_addr(PANCOORD_SHORT_ADD) function. Got the idea?

A request API call will most always be answered by a user confirm callback function. I'll walk quickly through the rest of the scenario beginning with the invocation of the mac_set_short_addr(PANCOORD_SHORT_ADD) function and allow you to follow the code in my tracks. The bullets with capital letters describe what is about to happen:

- SET MAC SHORT ADDRESS
- wpan_mlme_set_request
- usr_mlme_set_conf
- SCAN FOR LOWEST INACTIVE CHANNEL
- mac_active_scan
- wpan_mlme_scan_request
- usr_mlme_scan_conf
- START NEW PAN ON CHOSEN CHANNEL
- mac_start_pan()
- wpan_mlme_start_request
- usr_mlme_start_conf
- PERMIT END DEVICES TO ASSOCIATE WITH NEW PAN
- mac_set_assoc_permit(1)
- wpan_mlme_set_request
- usr_mlme_set_conf
- NEW PAN ESTABLISHED WAITING FOR ASSOCIATION REQUESTS
- State machine state is set to RUN using SET_STATE(RUN)
- AN END DEVICE REQUESTS ASSOCIATION
- usr_mlme_associate_ind
- REGISTER END DEVICE BY IEEE LONG ADDRESS
- mac_register_device
- POSITIVE ACKNOWLEDGEMENT TO ASSOCIATED END DEVICE
- wpan_mlme_associate_response
- WAIT FOR END DEVICE TO SEND DATA (BUTTON PUSH)
- usr_mcps_data_ind
- UPDATE LED PORT AND SEND BUTTON DATA TO ALL ASSOCIATED END DEVICES
- mac_send_data
- REPEAT PROCESS FROM usr_mcps_data_ind

We've just walked through the IEEE 802.15.4 coordinator code. Atmel also provides companion code for the end device in the same download. If you understand the drill here, you'll have no problem traversing the end device application source.

ZIGBEE OR IEEE 802.15.4??

Now you have a handle on what is ZigBee and what is IEEE 802.15.4. It's all been time well spent as you must have a firm grasp on IEEE 802.15.4 to be able to get your hands around ZigBee. By the way, MCPS is short for MAC Common Part Sublayer. The MCPS is the data portion of the MAC sublayer and resides in a logical manner next to the MAC's MLME. The MCPS services are accessed via the MAC sublayers data SAP. I found that most of my misunderstanding of ZigBee and IEEE 802.15.4 was aggravated by my inability to speak the language. If ZigBee or IEEE 802.15.4 projects are in your Design Cycle, picking up on the lingo is a must. **NV**

SOURCES

■ *Atmel Corporation* — ATAVR-RZ200 IEEE 802.15.4/ZigBee Demonstration Kit, AT86RF230, AVR Studio, JTAGICE mkII, ATAVRISP mkII
www.atmel.com

■ *IAR Systems* — Embedded Workbench for Atmel AVR, Evaluation Version v4.20A
www.iar.com

■ *ImageCraft* — ICCAVR
www.imagecraft.com

■ WinAVR
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■ ZigBee Specification
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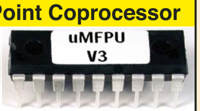

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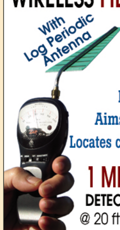

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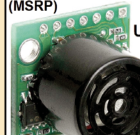

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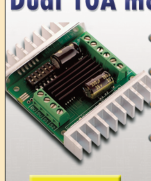

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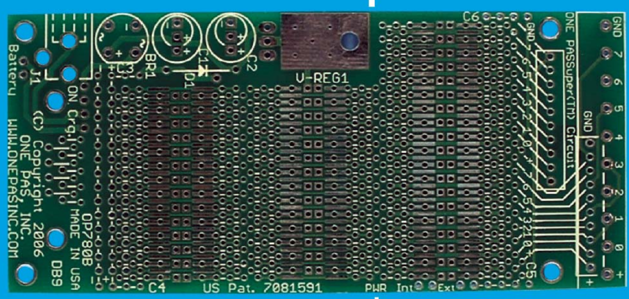

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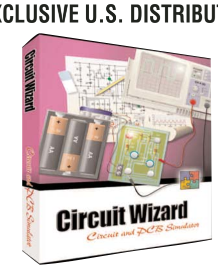

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 Continued from page 6

HAPPY WITH HISTORY

I had been a subscriber for a few years, and my wife let my subscription expire. So, I went on your website and re-subscribed. I have since received my third issue and this month I am especially proud of your great publication for remembering the history of "The Triode"and "The Great Pioneers" in our field. I have been in electronics most all my life, and at 64 I was beginning to think no one was interested in its history anymore. I am very happy to see that you aren't letting that important history go down the tubes. Thanks again and keep up the great work you are doing.

Rene Stover CET
Ellijay GA

POSITIVE OR NEGATIVE?

Regarding the November 06 article on the triode, page 69: Regenerative amplifiers are positive feedback devices, not negative feedback as stated.The focus on positive feedback, or regeneration, allowed the skilled operator to get the most out of the low-gain devices of the day, but had the over-whelming handicap of instability. The stability problem was helped a lot with the advent of the super-regen circuit sometime later.

The really great advances arose after the focus shifted to negative feedback, which improved stability at the expense of gain. The claimed invention of the negative feedback amplifier by Black (patented 1937) at Bell Labs is by some accounts suspect. However, whether Black really invented it or simply was the first to realize its benefits, the Bell folks lost no time in applying it to all manner of things. Except for the essential function performed by oscillators, electronics has mostly depended upon negative feedback devices since.

Orv Barr
Livermore, CA

FYI ON KITSRUS

In Chuck Hellebuyck's article on "USB PIC Programmers" in the October *Nuts & Volts* issue, he mentions those from kitsrus. I have been using two of these. One has a USB powered programmer (the K128) that, contrary to statements in the article, includes a ZIF-40 socket, as well as an ICSP. These programmers only program Flash PICs. The supplied software is excellent and, together with the firmware, automatically sets up the proper programming pins for the many supported PICs in the 40-pin ZIF.

The only drawback is that the firmware has not been updated for over two years and so does not include support for PICs like the 18F2550 (a favorite of mine). It does support PICs such as the 16F88 (another favorite). This may stem from the death last year of Peter Crowcroft, principal at kitsrus.

Ed Grens

AC POWER ON THE CLOCK

The Nixie clock on your cover (*Nuts & Volts* Vol. 27 No. 10) got my attention so I bought a copy, my first. I've now read the issue from cover to cover, and enjoyed much of the content, so please keep up the good work!

The Power Line Frequency Monitor project by Bob Armstrong was of interest as we tend to take the AC utility service for granted in this country, and how and why it is regulated was not clearly described in the article's text.

Utility companies regulate the AC power line frequency so that in a given 24 hour period, electric clocks remain accurate in the long term to within a few hundred parts per million. This is done by comparing a clock driven by the AC utility power against a similar one driven by a standard of known accuracy (traceable to an atomic clock standard), as it is known that the 60 Hz AC power line will complete 5,184,000 cycles in 24 hours. Typically, the daytime load on the utility slows the generators, or operators allow the voltage to drift downwards to reduce demand and avoid outages. This also slows down our clocks. During the night, the load is much lighter and operators allow the generators to speed up (higher line frequency) to sync clocks that use the power line frequency for timing. There are short term errors, typically less than 0.5 Hz, which the *N&V* project displays.

What would have been a nice feature on the project is an error display, as we already know the expected frequency is 60 Hz (or 50 Hz in some countries), and a fixed display of 60 Hz most of the time is redundant. How about a plus or minus percentage change or PPM (parts per million) display? Also, how about a daily readout of the previous day's maximum deviation and the time during the day that hit the highest and lowest frequency? While we're monitoring the AC line, how about a voltmeter function to record and display the instantaneous voltage, and its min and max? I think a multiple (or scrolling) display of several metrics would have greatly enhanced this project.

Peter

NEWS BYTES

Continued from page 57

NEW MCM CABLE SITE

MCM Cables has launched a new website at **www.mcmcables.com**. The MCM Cables.com website provides a total cable solution, offering a large variety and competitive pricing on cables for home theater, computer, networking, professional audio, and security applications. Features of the website include:

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Whether installing a new home theater system, whole-house audio system, security system, setting up a wireless network, or merely connecting cable to a TV, **www.mcmcables.com** has many options. **NV**

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MORE Electronic Gadgets for the Evil Genius
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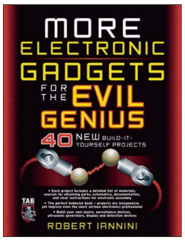

This much anticipated follow-up to the wildly popular cultclassic *Electronic Gadgets for the Evil Genius* gives basement experimenters 40 all-new projects to tinker with. Following the tried-and-true Evil Genius Series format, each project includes a detailed list of materials, sources for parts, schematics, documentation, and lots of clear, well-illustrated instructions for easy assembly. Readers will also get a quick briefing on mathematical theory and a simple explanation of operation along with enjoyable descriptions of key electronics topics. **$24.95**

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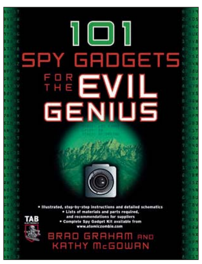

Utilizing inexpensive, easily-obtainable components, you can build the same information gathering, covert sleuthing devices used by your favorite film secret agent. Projects range from simple to sophisticated and come complete with a list of required parts and tools, numerous illustrations, and step-by-step assembly instructions. **$24.95**

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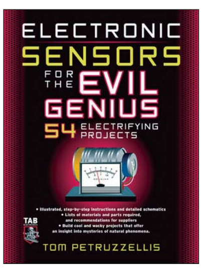
by Thomas Petruzzellis



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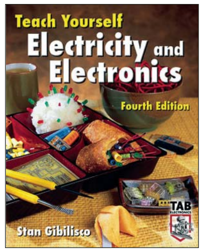

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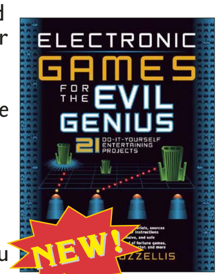
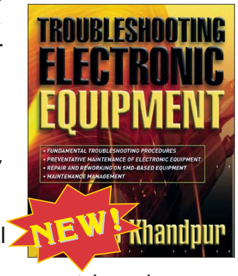
Electronic Games for the Evil Genius
by Thomas Petruzzellis



You can have a wicked amount of fun on your way to becoming a game master! In *Electronic Games for the Evil Genius*, popular how-to author Tom Petruzzellis gives you everything you need to build 35 exciting games and gadgets. You get complete, easy-to-follow plans, with clear diagrams and schematics, so you know exactly what's involved before you begin. Packed with fun projects that you'll love to build and play with, this guide develops game expertise one simple step and project at a time. **$24.95**

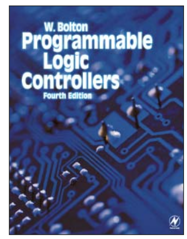
Troubleshooting Electronic Equipment
by R. S. Khandpur



From cell phones to medical instruments to digital and microprocessor based equipment, this hands-on, heavily illustrated guide clearly explains how to troubleshoot, maintain, and repair all types of electrical equipment. The author covers all the essentials such as necessary tools, soldering techniques, testing, fundamental procedures, and mechanical and electrical components. **$49.95**

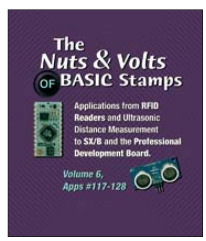
MICROCONTROLLERS

Programmable Logic Controllers — Fourth Edition
by W. Bolton



Now in its fourth edition, this best-selling text has been expanded with increased coverage of industrial systems and PLCs and more consideration has been given to IEC 1131-3 and all the programming methods in the standard. The new edition brings the book fully up to date with the current developments in PLCs, describing new and important applications such as PLC use in communications (e.g., Ethernet — an extremely popular system), and safety — in particular proprietary emergency stop relays (now appearing in practically every PLC based system). **$34.95**

Nuts & Volts of BASIC Stamps — Volume #6
by Jon Williams



Nuts & Volts of BASIC Stamps — Volume 6 includes articles #117-128, written for 2005. Article topics consist of RFID Readers and Ultrasonic Measurement, SX/B and the Professional Development Board, the advanced MIDI receiver, programming the SX microcontroller in BASIC, mastering the MC14489 display driver, and more! The Nuts & Volts of BASIC Stamps books are a favorite Parallax technical pick and are a tremendous technical resource for all PBASIC programming projects. **$14.95**

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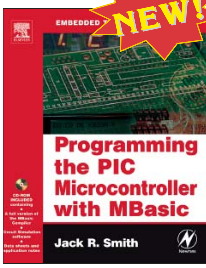
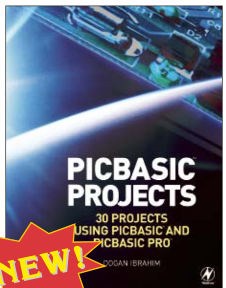
Programming the PIC Microcontroller with MBASIC
by Jack Smith



No microcontroller is of any use without software to make it perform useful functions. This comprehensive reference focuses on designing with Microchip's mid-range PIC line using MBASIC, a powerful but easy to learn programming language. It illustrates MBASICs abilities through a series of design examples, beginning with simple PIC-based projects and proceeding through more advanced designs. **$59.95**

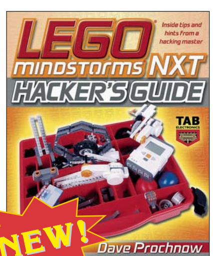
PIC Basic Projects
by Dogan Ibrahim



Covering the PIC BASIC and PIC BASIC PRO compilers, *PIC Basic Projects* provides an easy-to-use toolkit for developing applications with PIC BASIC. Numerous simple projects give clear and concrete examples of how PIC BASIC can be used to develop electronics applications, while larger and more advanced projects describe program operation in detail and give useful insights into developing more involved microcontroller applications. **$29.95**

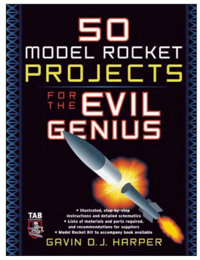
PROJECTS

LEGO MINDSTORMS NXT Hacker's Guide
by Dave Prochnow



Here is an awesome next-generation collection of LEGO MINDSTORMS projects that enables you to build and program a real working robot in just 30 minutes! New technologies and expanded sensor capabilities make it easier than ever to add a level of sophistication to robotic and architectural creations. The book explains the all-new NXT intelligent brick ... the interactive servo motors with rotation sensors that align speed for precise control ... the ultrasonic sensor that allows robots to "see" by responding to movement ... the improved light and touch sensors that let robots detect color and feel ... and much more. **$24.95**

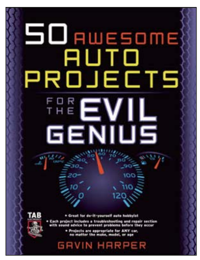
50 Model Rocket Projects for the Evil Genius
by Gavin D J Harper



The fun, hands-on way to learn about rocket science. Yes, as a matter of fact, is IS rocket science! And because this book is written for the popular Evil Genius format, it means you can learn about this fascinating and growing hobby while having fun creating 50 great projects. You will find a detailed list of materials, sources for parts, schematics, and lots of clear, well-illustrated instructions. **$24.95**

AUTOMOTIVE

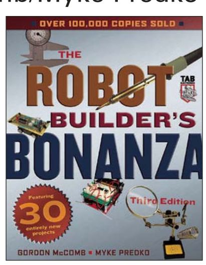
50 Awesome Auto Projects for the Evil Genius
by Gavin D J Harper



The Evil Genius format is the perfect "vehicle" for 50 incredible automotive projects that are compatible with any car, no matter what make, model, or year. Focusing on low-cost, easily obtained components, *50 Awesome Auto Projects for the Evil Genius* lists the items needed to complete each project along with a troubleshooting and repair section. **$24.95**

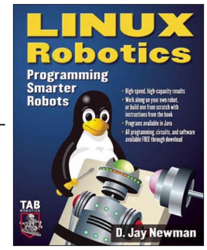
ROBOTICS

Robot Builder's Bonanza Third Edition
by Gordon McComb/Myke Predko



Everybody's favorite amateur robotics book is bolder and better than ever — and now features the field's "grand master" Myke Predko as the new author! Author duo McComb and Predko bring their expertise to this fully-illustrated robotics "bible" to enhance the already incomparable content on how to build — and have a universe of fun — with robots. Projects vary in complexity so everyone from novices to advanced hobbyists will find something of interest. Among the many editions, this book features 30 completely new projects! **$27.95**

Linux Robotics
by D. Jay Newman



If you want your robot to have more brains than microcontrollers can deliver — if you want a truly intelligent, high-capability robot — everything you need is right here. *Linux Robotics* gives you step-by-step directions for "Zeppo," a super-smart, single-board-powered robot that can be built by any hobbyist. You also get complete instructions for incorporating Linux single boards into your own unique robotic designs. No programming experience is required. This book includes access to all the downloadable programs you need, plus complete training in doing original programming. **$34.95**

SERVO CD-Rom

Are you ready for some good news? Along with the first 14 issues of *SERVO Magazine*, all issues from the 2005 calendar year are now available, as well. These CDs include all of Volume 1, issues 11-12, Volume 2, issues 1-12, and Volume 3, issues 1-12, for a total of 26 issues all together. These CD-ROMs are PC and Mac compatible. They require Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the discs. **$24.95 – Buy 2 or more at $19.95 each**

Nuts & Volts CD-Rom

Here's some good news for *Nuts & Volts* readers! Along with all 12 issues of *Nuts & Volts* from the 2004 calendar year, the 2005 issues are now available, as well. These CDs include all of Volumes 25 and 26, issues 1-12, for a total of 24 issues (12 on each CD). These CD-ROMs are PC and Mac compatible. They require Adobe Acrobat Reader version 6 or above. Adobe Acrobat Reader version 7 is included on the discs. **$24.95 – Buy 2 or more at $19.95 each**

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TECH FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams should be computer generated and sent with your submission as an attachment.*

QUESTIONS

To be considered, all questions should relate to one or more of the following:

1. Circuit Design
2. Electronic Theory
3. Problem Solving
4. Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).

■ Include your Name, Address, Phone Number, and email. Only your Name, City, and State will be published with the question, but we may need to contact you.

■ No questions will be accepted that offer equipment for sale or equipment wanted to buy.

■ Selected questions will be printed one time on a space available basis.

■ Questions are subject to editing.

ANSWERS

■ Include in the subject line of your email, the question number that appears directly below the question you are responding to.

■ Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address or we cannot send payment.

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■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

Does a sound level meter record transient sounds as well as higher amplitude sounds originating from a fundamental frequency? In other words, if I strike a pan or piece of wood, the impulse excites some fundamental frequency along with transients. The amplitudes of the various transients have varying amplitudes and usually some "fundamental" frequency which may have a higher amplitude. Do the various frequencies "add up" along with the fundamental (within frequency range of an SPL meter) to produce a reading in dBs? I am not certain how the SPl meter is working in reference to the entire frequency spectrum excited by the impulse. Can someone explain?

#12061 **Anonymous**
via email

I have a 12V 20W-halogen light that I want to use in my car by plugging it into the cigarette lighter receptacle. The alternator produces 13.8V to 14.1V. Can I just connect the cord to a cigarette lighter plug or do I need to reduce the voltage to 12V? If I need to reduce the voltage, could someone suggest a circuit that I can fit into the cigarette lighter plug?

#12062 **Kenneth Larsen**
via email

I want to build an inexpensive, simple, audio transmitting and receiving system (separate units) that can be connected to the stereo minijack output on an audio device/computer/ etc., and the receiver connected to speakers that have a stereo minijack input. I would like to have mutiple (3) receivers. I need a schematic for both the transmitting and receiving circuits.

#12063 **James**
Fullerton, CA

How do I interface a VGA monitor to use as a color monitor with ordinary video input?

#12064 **Rick Thompson**
via email

I need a 16-pin TCA280AI to repair an auto body spot welder. It is a general-purpose trigger circuit. Are there any companies that will sell me this chip without having to pay the typical $200 to $500 minimum fee for a $15 to $20 chip?

#12065 **Dave Stypula**
Johnstown, PA

As I travel the highways, I often wonder if the road is going up or down and by how much. One reason is that I might typically shut the air-conditioning compressor off when going uphill to save energy, but turn it on when going downhill as the engine is idling and the energy to drive the air-conditioner is essentially free.

GPS units are fairly accurate at computing altitude. Are directional accelerometers or GPS units sufficiently quick and accurate to produce such a signal? I have also seen digital levels that must produce an off level signal to send to a readout or display. How might these devices be used?

#12066 **Robert Fisher**
Owego, NY

I'm having a hard time clearing up excessive static on my AM radio reception, and I want to do time shift recording on my computer. I've purchased an external antenna, but the radio has to be close to this interference source, and even worse, it needs to be connected to it (limiting the distance I can move it). Anywhere in the room is going to have the same problem because of the amount of electronics ranging from flourescent lights to an office fridge.

Is there an easy way to build a Faraday cage around the radio, so that the interference generated within the room isn't a factor? Then if I use a shielded cable to bring in the external antenna signal from outside and use a ferrite core on the USB cable to the radio, will that stop the RF noise from feeding in through the signal/USB cables?

Unfortunately, I don't understand a lot of the technical aspects of Faraday cages and/or ferrite rings. If there is a good reference for this type of project to help me construct the cage (i.e., materials required as far as composition and structure) and/or select the ferrite ring (diameter, thickness, etc.) then I'd be happy to refer to it if someone could point the way.

I'd hate to spend a lot more time and money chasing a fundamentally flawed hypothesis, so I would appreciate any direction.

#12067 **William Parish**
San Diego, CA

>>>> ANSWERS

[#10064 - October 2006]

I need an alternator regulator circuit that will allow me to charge a 36-volt and a 72-volt battery bank using a standard automobile alternator (75-100 amp type alternator). Any ideas?

#1 You need to read *Alternator Secrets* by T. J. Lindsay, available at **www.lindsaybks.com**. For $3, you will have all you need to know about how to modify an alternator output to the voltage you need. The quick summary of about 20 pages of information is that you need to add resistance between the zener diode and the resistance bridge in the regulator circuit to raise the voltage.

Steve Benson
New Castle, IN

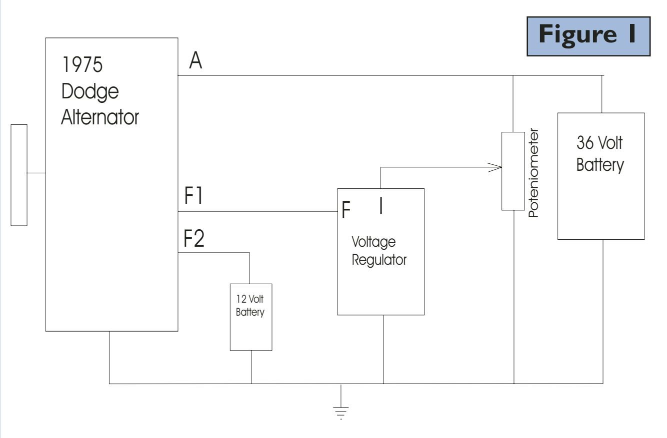


Figure 1

#2 Shown in Figure 1 is a way to charge higher voltage batteries using an old style alternator with an external regulator. The regulator adjusts the field to cause the voltage at the I input of the regulator to be 14.4 volts. The potentiometer is used to divide the charging voltage down to 14.4 volts. I do not know what the current requirements of an old Chrysler regulator would be, so I have not indicated a value for the potentiometer. You would have to measure the current and choose a reasonable value. Of course, fixed resistors can be used. The diode pack in the alternator should be good for 40 to 50 volts, maybe even higher. I have seen an old Chrysler alternator put out 300 volts and the diodes did not blow. All you can do is try it. The RPM will have to be quite high to get any current at high voltages. Do not expect to get 80 amps out of an 80-amp alternator.

These same modifications can be made to an alternator with an internal regulator. It would have to hacked to find the equivalent of the I and F terminals to the internal regulator.

Steven Schmitt
Rochester, MN

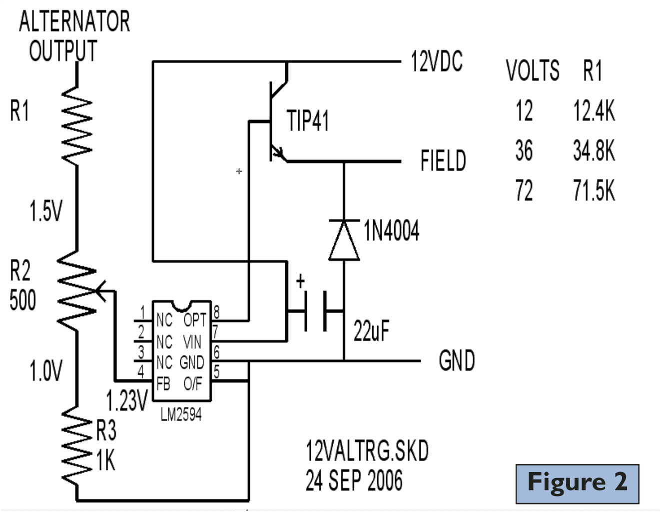


Figure 2

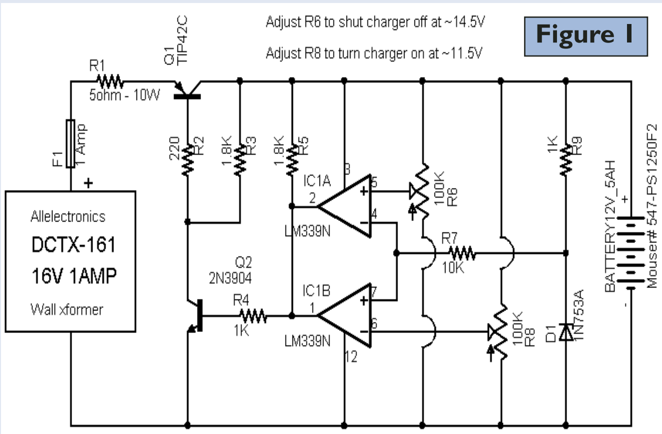
#3 Figure 2 is a modification of a design I did for my tractor alternator. The alternator will put out 72 volts with 12 volts on the field if you turn it fast enough. It is only necessary to change R1 to change the regulated voltage. You could install them with a three-position switch.

Russell Kincaid
Milford, NH

[#10061 - October 2006]

I've noticed recently some very bright LEDs hitting the market. I was wondering that since these LEDs need one watt at about 3 VDC, it would be perfect for a photovoltaic system. I'm looking for a circuit diagram and parts list for something that will change 12 VDC to 3 VDC. Also, I will need the same for a switching system that will turn on a line charger when the batteries get low and a recommendation as to battery type to use.

Figure 1



#1 To reduce 12 volts to three in a photovoltaic system, a buck regulator is preferable to a linear regulator, because the buck regulator will waste far less power. There is a complete schematic diagram of a buck regulator on page 15 at **http://focus.ti.com/lit/ds/symlink/tps54350.pdf**

It provides a regulated 3.3V at up to three amps. Install a one ohm resistor in series with the LED to limit the current.

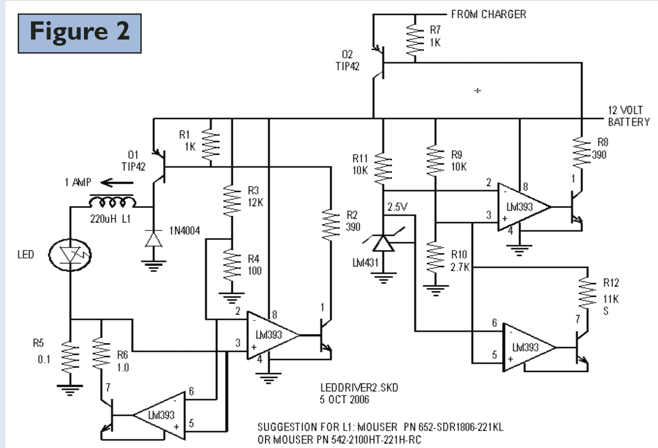
Your second question asked for a recommendation for a battery and a charger control circuit. Mouser sells a 12 volt, 5 AH battery (#547-PS1250F2) for $12.72 and the regulator chip mentioned above (#595-TPS54350PWP) for $4.92.

Regarding the charger, I would recommend you opt for a pre-made solution: catalog #BC-212 from All Electronics for $12.75 **www.allelectronics.com**

Ed Schick
Harrison, NY

#2 I think you meant to say one amp and three volts; one watt and three volts would be 333 mA but this circuit can work in either case. Since the load is an LED, it is much better to regulate the current rather than the voltage, because the forward voltage is not well controlled. This circuit in Figure 2 maintains one amp current through the LED and you can have up to three LEDs in series. To reduce the current, make R5 larger. The current limit is when the voltage across R5 reaches 100 mV. All the resistors — except R2 and R8 — can be 1/8 watt. R2 and R8 should be 1/2 watt. The transistors Q1 and Q2 should not need any heatsink because they are switched on or off. There are two circuits: Q1 is part of a switching circuit to regulate the LED current; Q2 is part of a circuit to charge the battery. When the battery voltage drops to 11.5 volts, Q2 turns on. Positive feedback through R12 keeps it turned on until the battery voltage rises to 14 volts. The transistor shown as part of the LM393 is internal. I drew it that way to emphasize that it is open collector output. The LM431 is a shunt regulator, AKA TL431. I have not built this, so no guarantee. I would use a gel cell; they are inexpensive, available, and will last as long as any if kept charged.

Figure 2



Russell Kincaid
Milford, NH

#3 LEDs are current devices. They are typically specified with a forward voltage (Vf) and current. The forward voltage is the typical drop across the LED at a specified current. The LED will not illuminate until the forward voltage is exceeded. LEDs may be placed in series with a single resistor limiting the current or in parallel with a resistor in series with each LED.

The current of the LED using Ohm's law would be 3V/1W or 300 mA per LED. To use any number (n) of the LEDs that you describe, at any reasonable supply voltage, size the resistor from R = (Vsupply-Vf*n)/300E-3. n*Vf should be less than the supply voltage. For a 12V supply, the resistance would be (12-3)/300mA or 30 ohms.

The wattage of the resistor also needs to be determined from P=VI. Substituting; P = (12-3)*300e-3 or 2.7 W. Two 15 ohm, five watt metal oxide resistors from Digi-Key would be a good choice. Metal oxide resistors tend to vaporize completely if overstressed acting somewhat like a fuse. There are large error bars on just about every parameter.

The battery charger used is dependent on the battery chemistry and the choice of battery is dependent on the application. Each battery chemistry has its own set of rules that maximize battery life. Lead acid and Ni-Cad are both worth mentioning. Lead acid comes in a deep cycle version which means the battery will not be damaged when the battery is deeply discharged. Automotive batteries are not deep cycle and will damage easily when their charge is depleated. Ni-Cd batteries like to be deeply discharged and then fully charged, otherwise they develop a memory effect.

Ron Dozier
Wilmington, DE

[#11063 - November 2006]

Car computers are becoming more and more popular. It seems that the one common thing not available is a good USB AM-FM stereo tuner, which is necessary to rid the car of the in-dash radio and have space to put the computer's screen. I have tried several of the commercially available USB tuners (Radioshark, D-Link, Hauppage). All of them seem to suffer from the same poor sensitivity, especially when used in the automobile environment.

Has anyone built a high quality AM-FM stereo USB tuner, or know of a magazine dedicated to car computers?

The reader should check out the website **www.mp3car.com** for information regarding USB AM/FM radios for use in a car computer. In the forums, under the Hardware Development section, there are many threads about the need for, and development of, a USB-controlled AM/FM radio with RDS/RDBS funtionality.

The radio just went on sale on October 27th, after many months of development.

Here is the link to the product: **www.xtronic.be/?id=91&lang=2**

Chris
Parker, CO

[#11064 - November 2006]

I have a new ICOM IC-R1500 wideband receiver and was wondering if, or how, I could listen to raw GPS data? I have scanned the L1 frequency of 1559.4610 MHz, but all I hear is noise. Likewise result on the L2 frequency of 1227.60 MHz. I would assume that I could at least hear a burst of data once per second?

My antenna is a roof-mounted AOR DS3000A 75 MHz to 3,000 MHz wideband discone. Perhaps I need an antenna tuned to 1,560 MHz and possibly a high-gain amplifier, to boot?

#1 I found this site, a forum discussing discone antennas: **www.radioreference.com/forums/showthread.php?t=15574.**

The receiver is more sensitive at FM than at wideband FM, so use that setting, but if it is possible to set the receiver to AM, that will be even more sensitive. The computer won't be able to decode the signal on AM, but you should be able to hear it. The discone antenna has no gain, so you will be much better off with a dish antenna or a yagi. If you are using the common RG58 cable, the loss at 1.5 GHz is 0.2 dB per foot. You could be losing half the signal in the cable. With 6 dB gain at the discone antenna and receiver set to AM, you should hear the signal. If you don't, look for a problem with the connections or the receiver.

Russell Kincaid
Milford, NH

#2 GPS is a completely digital data system operating in a Right Hand Circularly Polarized, Bipolar-Phase Shift Keying mode. The data modulation rate is about 1.023 MHz. The C/A code repeats every millisecond for each satellite so the noise you are hearing is the raw GPS data from every GPS satellite (Space Vehicle or SV) currently above your local horizon since they all broadcast on the same frequency. There is no broadcast of Latitude and Longitude that you could decode with your radio set as you were hoping.

At a very basic level, each SV is continuously broadcasting a complex signal indicating things such as overall network health and all SV positions within the constellation modulated on the appropriate frequency with a timing signal. The receiver (even your handheld hiking one) is a multi-channel receiver tuned to L1. L2 is used more by the high-end survey-grade GPS receivers that can cost up to $20,000 each. Each channel in the receiver tracks 1 SV's broadcast. Once enough data is received on a channel, the GPS receiver can estimate its distance from the particular SV. As more SVs ranges are determined and added to the solution, the receiver's position becomes an exercise in finding the intersection of overlapping spheres. More SVs in the solution result in a smaller possible intersection point, thus a better position.

If you ever wondered why it takes so long for your GPS receiver to start working again after not being used for six months (or why the cold start time can be five minutes long), it's the ephemeris' fault. The ephemeris is a table of SV positions so the receiver has a base position to start from. This data is constantly being refreshed as the constellation changes geometry. If the GPS receiver cannot correlate the ephemeris in its memory to what is being broadcast, then it has to wait for the data to be resent before processing.

If you really want the very gritty details of the signal, you can read the GPS signal specification from the Coast Guard website at: **www.navcen.uscg.gov/pubs/gps/sigspec/default.htm**

Tom Homan
Globe, AZ

#3 The GPS signal is a very precise (atomic clock), continuous time code that is encoded in a pseudorandom noise, and that is why you hear noise. There are no finite signal bursts since GPS is used by things that travel great distances during one second and need to know where they are at any instant in time. The signal may have so much bandwidth that it is indistinguishable from background noise to your ears (for precision and redundancy reasons, certainly not for data quantity).

The GPS streams are decoded into the amount of time the signals took to reach you from the satellites by GPS units — which use that as distance information — and then they calculate where the unit is based on the known geometry of the distances between the GPS device and the satellites.

For accurate time information, tune in shortwave time standard stations, such as WWV, CHU, MSF, etc.

GPS position decoders are not Do-It-Yourself tech for most hobbyists.

APRS may be related (or alternative) to what you are looking for.

William Como
Bethpage, NY

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150W Series Available in 5,7.5,9,12,24,28,36V	$48.99	$44.09ea	$39.00ea	$37.50ea	$26.93ea	$23.49ea

Programmable DC Power Supplies

The CSI 3600 Series Programmable DC Power Supplies are equipped with a back-lit LCD display, number keypad and a rotary code switch for ease of use & quick programming. Voltage, Current & Power can all be displayed on the LCD or computer screen (with optional RS-232 interface module). It can be operated at constant current mode, constant voltage mode & constant power mode. It also can be set with maximum limits for current & power output. Ideal instruments for scientific research, educational labs or any application requiring a sophisticated DC-power source.

Model	CSI3644A	CSI3645A	CSI3646A
DC Voltage	0-18V	0-36V	0-72V
DC Current	5A	3A	1.5A
Power (max)	90W	108W	108W

Only $199.00 Each!

www.CircuitSpecialists.com

Programmable DC Electronic Loads

The CSI 3700 series electronic loads are single input programmable DC electronic loads that provide a convenient way to test batteries and DC power supplies. It offers constant current mode, constant resistance mode and constant power mode. The backlight LCD, numerical keypad and rotary knob make it much easier to use. Up to 10 steps of program can be stored.

Model	CSI3710A	CSI3711A
Input Voltage	0-360V DC	0-360V DC
Input Current	0-30A DC	0-30A DC
Input Power	0-150W	0-300W

CSI3710A: $349.00 **CSI3711A: $499.00**

Circuit Specialists Soldering Station w/Ceramic Element & Seperate Solder Stand

$34.95!

- Ceramic heating element for more accurate temp control
- Temp control knob in F(392° to 896°) & C(200° to 489°)
- 3-prong grounded power cord/static safe tip
- Seperate heavy duty iron stand
- Replaceable iron/easy disconnect
- Extra tips etc. shown at web site

Item# **CSI-STATION1A**

Rapid Heat Up!

Also Available w/Digital Display & MicroProcessor Controller

Item# **CSI-STATION2A**

$49.95

Details at Web Site

SMD Hot Tweezer

Adaptor Fits **CSI Stations 1A & 2A** and **CSI906**

$29.00

Item# **CSITWZ-STATION**

> Soldering Equipment & Supplies > Soldering Stations

In Business

Circuit Specialists Inc.

Since 1971

Protek Dual Trace 100MHz Oscilloscope

Outstanding performance and durability for an incredibly low price of $519. You will find it at most other locations selling for $975.

- Four traces may be simultaneaously displayed in ALT-sweep
- Five vertical Modes Chl, Ch2, Dual, Add and Subtract
- Bright 6" CRT with an internal graticule
- 12 kv acceleration voltage
- Sweep speeds to 2nS/Div.

Limited Offer **$519.00!**

Item# **6510**

Details at Web Site > Test Equipment > Oscilloscopes/Outstanding prices

6-1/2 Digits Digital Multimeter

PICOTEST

- Stability, Speed and Accuracy
- High Performance: 2000 readings/sec
- Multi-Point Scan
- 19 Full-Featured Functions
- Dual Displays with 3-color Annunciators
- Noise Immunity.
- Built-in USB and GPIB (optional) Interfaces
- Easy & Free PC applications
- 6 1/2 Digits M3500A Specifications
- Optional Accessories
- Designed with 7-1/2 digit techniques to provide user a stable, faster and accurate measurement.
- 1000VDC / 750VAC

Compare Price & Specs with the Agilent 34410A !

Item# **M3500A**

$689.00

Details at Web Site

> Test Equipment > Digital Multimeters

Dual Output DC Bench Power Supplies

High stability digital read-out bench power supplies featuring constant voltage and current outputs. Short-circuit and current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance and long life.

As Low As $93.00!

- Source Effect: 5×10^{-4}=2mV
- Load Effect: 5×10^{-4}=2mV
- Ripple Coefficient:: <250uV
- Stepped Current: 30mA +/- 1mA

HOT ITEM!

*All 3 Models have a **1A/5VDC Fixed Output** on the rear panel*

CSI3003X-5: 0-30v/0-3amp 1-4: **$105.95** 5+: **$99.50**
CSI5003X5: 0-50v/0-3amp 1-4: **$114.95** 5+: **$109.00**
CSI3005X5: 0-30v/0-5amp 1-4: **$119.00** 5+: **$114.00**

Details at Web Site > Test Equipment > Power Supplies

Triple Output Bench Power Supplies

with Large LCD Displays

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1ea. fixed output @ 5VDC@3A
- Source Effect: 5×10^{-4}=2mV
- Load Effect: 5×10^{-4}=2mV
- Ripple Coefficient: <250uV
- Stepped Current: 30mA +/- 1mA
- Input Voltage: 110VAC

CSI3003X3: 0-30VDCx2 @3A **$188.00** 5+: **$183.00**
CSI3005XIII: 0-30VDCx2 @5A **$239.00** 5+: **$229.00**

Details at Web Site > Test Equipment > Power Supplies

ESD Safe CPU Controlled SMD Hot Air Rework Station

The heater and air control system are built-in and adjusted by the simple touch of the front keypad for precise settings. Temperature range is from 100°C to 480°C / 212°F to 896°F, and the entire unit will enter a temperature drop state after 15 minutes of non-use for safety and to eliminate excessive wear.

Item# CSI825A++ **Sale $149.00!**

- •CPU Controlled
- •Built-in Vacuum System
- •Temperature Range:100°C to 480°C / 212°F to 896°F
- •15-Minute Stand-By temperature "sleep" mode
- •Power:110/120 VAC, 320 W maximum

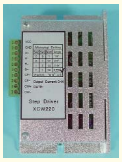
Details at Web Site > Soldering Equipment & Supplies

Stepper Motors

Part #:	Motor Frame Size:	Holding Torque:	Price:
42BYGH404	NEMA 17	3.4kg.cm/47oz.in	$17.95
57BYGH207	NEMA 23	8kg.cm/111oz.in	$24.95
57BYGH303	NEMA 23	15kg.cm/208oz.in	$29.95
57BYGH405	NEMA 23	20kg.cm/277oz.in	$34.95
85BYGH350B-03	NEMA 34	48kg.in/665oz.in	$79.95
85BYGH350C-03	NEMA 34	63kg.cm/874oz.in	$119.95

Stepper Motor Controllers 2 Phase Microstepping

Stepper Motor Driver (Bi-polar & Unipolar Motors)



Part #:	Dimensions:	MicroStep:	Price:
XCW220	100mm x 61mm x 19mm	1(200), 1/2(400), 1/4(800), 1/8(1600)	$39.95
CW220	99mm x 65mm x 30mm	1/2(400), 1/8(1600)	$49.95
CW230	115mm x 72mm x 32mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800)	$59.95
CW250	140mm x 94mm x 45mm	1(200), 1/2(400), 1/8(1600)	$69.95
CW860	147mm x 97mm x 30mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800), 128(25600), 1/5(1000), 1/10(2000), 1/25(5000), 1/50(10000), 1/125(25000), 1/250(50000)	$119.95

Breadboard / Power Supply / MultiFunction DMM Bundle

Provides the user with a quick and efficient system for breadboarding electronic circuits. Comes with three built-in regulated power supplies along with a deluxe, easy-to-use breadboard. Included is a multifunction DMM with 100VDC, 750VAC, frequency, resistance, diode test, audible continuity, transistor check,temperature, and capacitance.

A Super Deal!

Details at Web Site

> Breadboards & Prototyping Boards

Powered Breadboard w/out DMM: $69.00

Only $69.99!

Item#: PBB272-DMM: $69.99!

Powered Breadboard w/Multifunction DMM (CSIMS8264)

You Get The DMM for an Extra $.99

Digital Storage Oscilloscope Module

PC based Digital Storage Oscilloscope, 200MHz 5GS/s equiv. sampling USB interface

Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC basedscope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

Details & Software Download at Web Site

Price Breakthrough!

> Test Equipment > Oscilloscopes/Outstanding Prices

Item# 200DSO Only **$819.00**

FLUKE®

Fluke TI30 Thermal Imager

- •Temperature Range: -10° to 250°C (14° to 482°F)
- •Detector type: 120 x160 thermal element focal plane array (FPA) uncooled microbolometer
- •Accuracy: ±2% or ±2ºC
- •Repeatability: ±1% or ±1ºC (±2ºF) whichever is greater
- •Temperature Indication Resolution: 0.1 (ºF or ºC)
- •NETD: 200 mK
- •Spectral Range: 7-14 microns

List Price: $9995.00

Item# FLUKE TI30

Special Purchase $6699.00! Limited To Stock On Hand!

Details at Web Site

> Test Equipment > Fluke Test Equipment

Protek

2MHz Sweep Function Generator

- •0.02Hz-2MHz(7 Ranges)
- •Sine,Triangle,Square,Pulse,Ramp, Slewed Sine Waveform
- •Sync. Out (TTL Square Waveform)
- •Accuracy: ±5% of Full Scale to 200KHz, ±8% of Full Scale from 200KHz-2MHz
- •Sweep Function
- •VCG Input

Item# PROTEK 9205

Special $129.00! Any Quantity

Details at Web Site

> Test Equipment > Function Generators

SONY Super HAD CCD Color Weatherproof IR Cameras

- •Day & Night Auto Switch
- •Signal System: NTSC
- •Image Sensor:1/3" SONY Super HAD CCD
- •Horizontal Resolution: 480TV lines
- •Min. Illumination: 0Lux

480 TV Lines Resolution

Item# VC-827D: **$132.00**

SONY Super HAD CCD™ equipped camera's feature dramatically improved light sensitivity

SONY Super HAD CCD B/W Weatherproof IR Camera

- •Day & Night Auto Switch
- •Signal System: EIA
- •Image Sensor: 1/3" **SONY Super HAD CCD**
- •Horizontal Resolution: 420TV lines
- •Min. Illumination: 0Lux

Item# VC-317D: **$59.50**

Details at Web Site

SONY Super HAD CCD Color Camera

- •Weather Proof
- •Signal System: NTSC
- •Image Sensor: 1/4" SONY Super HAD CCD
- •Horizontal Resolution: 420TV lines
- •Min. Illumination: 1Lux/F1.2

Item# VC-805: **$53.95**

> Miniature Cameras(Board,Bullet,Mini's, B/W, Color)

SONY Super HAD CCD Color Weatherproof IR Camera

- •Day & Night Auto Switch
- •Signal System: NTSC
- •Image Sensor: 1/4" **SONY Super HAD CCD**
- •Horizontal Resolution: 420TV lines
- •Min. Illumination: 0Lux

Item# VC-819D: **$62.50**

Visit our website for a complete listing of our offers. We have over 8,000 electronic items on line @ www.CircuitSpecialists.com. PC based data acquisition, industrial computers, loads of test equipment, optics, I.C□s, transistors, diodes, resistors, potentiometers, motion control products, capacitors,miniature observation cameras, panel meters, chemicals for electronics, do it yourself printed circuit supplies for PCB fabrication, educational D.I.Y. kits, cooling fans, heat shrink, cable ties & other wire handleing items, hand tools for electronics, breadboards, trainers, programmers & much much more! *Some Deals you won't believe!*